Sewage Works

SLUDGE DIGESTION EXPERIENCES WITH THE EXTERNAL HEAT EXCHANGER*

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Interior hot water coils for heating a digester have frequently been installed with the realization that at sometime or other the digester might have to be emptied unexpectedly in order to permit repair or cleaning of coils. To eliminate this problem, the Urbana and Champaign Sanitary District decided to install an external heater and heat exchanger for its new sludge digester, built in 1945–46. The decision was made with some slight misgiving, since there had been no previous experience with the unit in a municipal treatment plant. It was felt, however, that tests which had otherwise been made were reliable and offered sufficient proof of success. The unit installed is the product of the Pacific Flush Tank Company (1).

The heat exchanger was installed in conjunction with the construction of additional primary treatment units, including a mechanical screen, two Parshall measuring flumes, a sedimentation tank and separate digester. Heretofore a hand-cleaned bar screen and four Imhoff tanks constituted primary treatment.

The heat exchanger was placed in operation in April, 1946 and has been used continuously to date, except when hot weather eliminated the need for constant operation. Time required for inspection and minor parts replacement has been negligible.

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Heat Exchanger Description

The unit has a normal output rating of 250,000 B.t.u. per hour at a thermal efficiency of approximately 80 per cent. At this rating the unit consumes 480 cu. ft. of gas per hour (assuming a gas heat value of 650 B.t.u. per cu. ft.). It requires a relatively small amount of floor space, overall dimensions being 4 ft. in width, 10 ft. in length (including sludge suction and discharge pipes) and 8 ft. in height. Safety devices are provided to give automatic protection against failure of the pilot, main gas supply, power supply, and against excessive water bath temperature. The unit is shown in Figure 1, and is further described elsewhere (1).

Other than the required sludge and gas connecting lines, the following auxiliary equipment is installed for proper operation and control of the heating system: (a) American Well Works cutting type, centrifugal sludge circulating pump with U. S. Motors varidrive, permitting variation of pumping rates from 80 to 200 g.p.m.; (b) Sprague No. 4 gas meter; (c) gas line flame trap, pressure indicating gauge and manual control valves; (d) standby Carter duplex plunger pump, normally used for pumping raw sludge to digester; (e) Builders-Providence venturi sludge meter, and recorder; and (f) Foxboro digester temperature indicating thermometer.

Description of Digester Facilities

The single digester used in conjunction with the heat exchanger is a 45-ft.

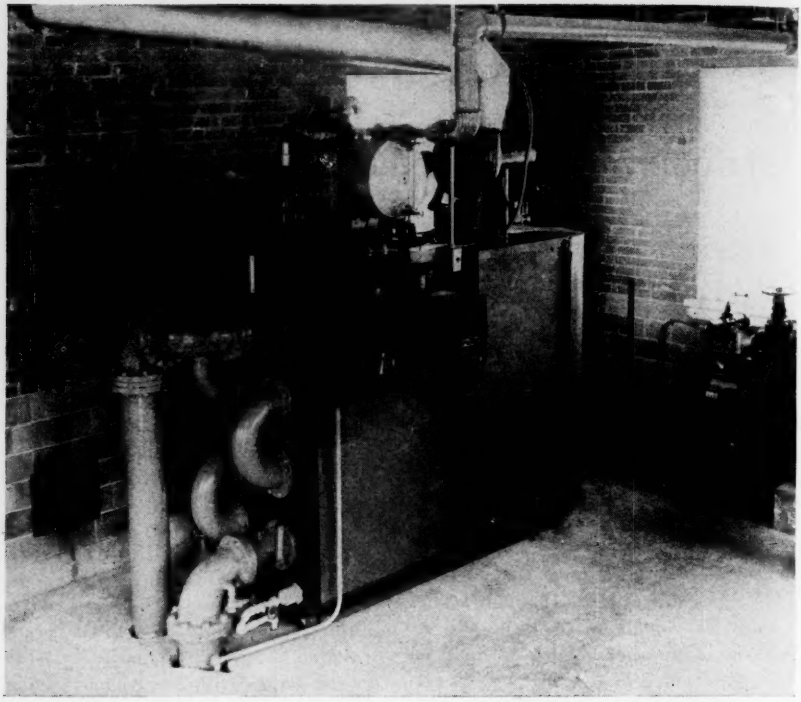

FIGURE 1.—Heat exchanger used for heating sludge at Urbana-Champaign, Ill.

diameter, floating cover type (Figure 2). The normal point of suction for the circulating pump is at 706.5, a level where supernatant liquor would ordinarily be found. The normal discharge from the heat exchanger is at the top center of the tank, as indicated.

Additional points of suction for recirculation are also provided at the tank edge 16 in. and 6 ft. above the bottom, and at the bottom-center of the tank. One additional discharge point is provided by the normal raw sludge inlet, which lies about 6 ft. above the bottom and extends horizontally two-thirds of the distance to the tank center.

Raw sludge may be mixed with the circulating sludge and routed through the heat exchanger for preheating, or it may be pumped directly into the digester through the raw sludge inlet pipe at 700.67. A selector screen, gauge and sight-glass are provided for supernatant withdrawal. Supernatant may also be withdrawn through any one of five 3-in. sampling pipes (shown in broken lines on the left in Figure 2), which are connected to the selector gauge and sight-glass for controlling the rate of flow.

The digester (and settling tank) were installed primarily to relieve the heavy load on the four Imhoff tanks. With its 34,000-cu. ft. capacity the digester normally takes raw sludge from 40 per cent of the incoming sewage, while the Imhoff tanks, with 100,000 cu. ft. of digestion capacity, take the balance. This 2 to 3 loading ratio is adhered to since it represents the actual sedimentation capacity ratio. The loading ratio can be varied at will and has, during test periods, been altered considerably.

The scum from the separate primary

sedimentation tank and the humus from the final settling tanks have always been returned to the Imhoff tanks. Since the first 6 months of digester operation, the supernatant, or top sludge, has also been routed to the Imhoff tanks.

Starting Operation

The digester was filled with sewage in early April, 1946, and after repairing several minor leaks in the wall and cover, heating of the tank was begun. A temporary oil burner, installed in the heater by the manufacturers, was placed into operation on April 14, with the tank temperature at 53° F. The oil burner remained in service for one month, using 1,470 gal. of No. 2 fuel oil to bring the temperature to 82° F. During that time about 36,000 gal. of sludge (13,300 lb. dry solids) was pumped from the Imhoff tanks to seed the digester.

The first raw sludge was pumped to the tank on May 8, though a daily routine of pumping was not adopted until 12 days later. On the 15th the first gas was collected. The volume produced increased rapidly, and two days later heater operation with gas was begun.

No difficulty was encountered in the starting operation, nor was any experienced in changing from oil to gas. The heater has operated on gas ever since. No provisions have been made for auxiliary heating because seed sludge from the Imhoff tanks will always be available if emptying of the digester should become necessary.

Operating Routine and Time Requirements

Before starting the heater the gas supply is checked to be certain that it is adequate. In this case the control valve is set to discharge about 9 cu. ft. of gas per minute to the heater. The unit will operate on less than the rated input capacity, but some adjustment of primary and secondary air inlets may then be necessary.

The circulating pump is then placed in operation. This pump normally operates at 140 g.p.m., which is equivalent to 201,600 g.p.d. or about 80 per cent tank turnover per day. Throwing the main switch at the heater starts the blower, as well as the warning horn,

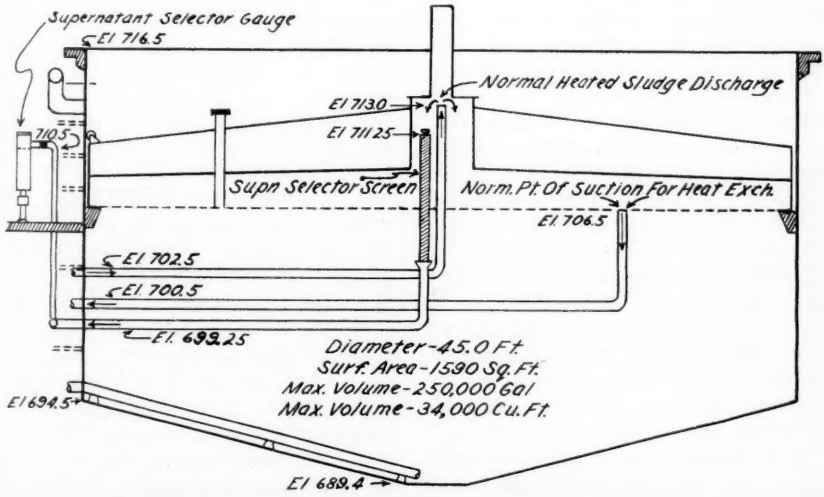

FIGURE 2.—Details of sludge digester, Urbana-Champaign, Ill.

which sounds until the pilot spark button is pushed, lighting the pilot gas flame. If the water bath control calls for heat the solenoid valve on the main gas supply line opens and the gas lights immediately.

The heat exchanger contains eight 4-in. sludge heating coils. By a simple interchange of return bends at the rear of the unit, the heater may be operated with sludge circulating through four, six or eight coils. It has been found that with eight coils in operation the temperature of the circulating liquor at the outlet ranges from 6 to 8 degrees higher than at the inlet; with six coils in use the temperature rise is 2½ to 3 degrees; and with only four coils in use the rise is 1½ to 2 degrees. In general the temperature rise will depend on the circulation rate, the solids content of the circulating liquor and the difference in temperature between it and the water bath.

The routine schedule includes reading of the thermometers, gas meters and pressure gauges every four hours. Only the 8 A.M. readings are entered on monthly records, but all readings have thus far been kept for possible future reference. Once daily the safety features of the heater are tested. Permanent records are kept to show the hours of operation, pilot failures, mechanical failures and power failures.

The heat exchanger and circulating pump are normally in operation 24 hours daily, except during summer months. Since October, 1947 an effort has been made to maintain the digester at 95° F. and this has been accomplished with ease. It has been maintained by manual control of the water bath temperature limits, the upper limit usually remaining constant at 180°, with the lower limit being varied between 100° and 170° depending on the tank heat losses due to temperature of the air and raw sludge.

Raw sludge is pumped three times daily, two of the pumpings being mixed with circulating sludge and one being routed directly to the raw sludge inlet. The sludge meter is located on the latter line, and the one daily pumping through it is made as a check on the raw sludge pumping rate.

Costs of Installation and Operation

The initial cost of the heater and auxiliaries was about $2,600, roughly equal to that which would have been necessary for the usual gas boiler, heating coils and auxiliaries. Since some installations would normally provide piping and a pump for sludge recirculation regardless of the means used for heating the digester, the initial cost could, in such cases, be regarded as lower for the outside heater.

The time requirement for operation is about the same as that for a gas boiler installation. Power costs are probably higher than for gas boiler and coil heating in proportion to the installed horse power. The motors on the pump and blower for the heater are 3 and 1½ h.p. respectively and would require a maximum of 80 kw.-hr. daily under full load, equivalent to $1.20 per day. While there is no direct means of measuring this power consumption, a comparison of power bills indicates that the cost is not greater than $0.75 per day. It is considered that this cost is more than offset by the accessibility of the heater for repairs, and the elimination of any apprehension regarding emptying of the digester.

Maintenance Experience

There has actually been less mechanical difficulty than might be expected from this type of equipment. The sole replacements required during the 2-year period include one electronic vacuum tube on the "Flameotrol"; one V-belt; and one pulley on the shaft of the blower motor, the latter being the result of a loose setscrew.

Some difficulty was experienced with the pilot and main gas burner beginning in late fall, 1946. A gassy odor

TABLE I.—Temperatures, Capacities, and Heat Exchanger Data

Month	Physical Conditions				Heat Exchanger Operation			
	Ave. Outside Air Temp. (° F.)	Ave. Raw Sludge Temp. (° F.)	Ave. Digester Temp. (° F.)	Ave. Dig. Capacity (1000 cu. ft.)	Ave. Hr./Day Heat Exch. Optg.	Ave. Hr./Day Circ. Pump Optg.	Gas Used Per Mo. (1000 cu. ft.)	Ave. Gas Used Per Hr. (cu. ft.)
May, 1946	58.8	62	82	29.7	18.08	19.10	—[1]	—[1]
June	71.3	65	91	29.2	17.70	17.90	—	—
July	74.8	71	91	30.2	10.67	10.90	57.4[2]	250
Aug.	70.1	71	88	28.2	10.22	10.93	163.9	484
Sept.	66.8	70	93	29.5	10.00	11.68	195.2	558
Oct.	60.6	69	91.5	31.4	12.42	13.73	218.6	513
Nov.	45.4	66	90	31.6	16.23	17.42	205.3	392
Dec.	36.0	62	89	30.4	23.77	23.88	335.9	454
Jan., 1947	32.0	58	88	29.8	23.57	23.57	468.8	643
Feb.	24.2	56	88	30.1	24.00	24.00	482.7	722
Mar.	34.0	56	87.5	33.3	23.47	23.47	498.3	684
Apr.	51.4	57	89	33.8	23.48	23.42	272.8	388
Yearly Total	—	—	—	—	—	—	2898.9	—
Average	52.2	63.5	89	30.6	17.80	18.33	289.9	509
May, 1947	58.6	58.5	93	32.1	16.90	18.52	170.8	326
June	68.6	63	92.5	30.2	18.42	19.68	169.3	306
July	72.6	65	94.5	30.0	23.70	23.70	156.7	213
Aug.	80.8	70	93	29.8	10.53	10.78	73.1	224
Sept.	67.8	69	92	31.1	18.97	18.97	157.2	276
Oct.	63.4	68.5	95.5	29.8	24.00	24.00	169.5	228
Nov.	37.4	64.5	94	29.5	23.98	23.98	218.5	304
Dec.	33.3	59.5	95	31.3	23.82	23.88	241.0	327
Jan., 1948	22.8	55.5	95	31.1	23.97	24.00	273.6	368
Feb.	29.8	54.5	95	31.1	24.00	24.00	247.1	355
Mar.	40.0	54	95	31.5	23.22	24.00	228.3	317
Apr.	54.0	57	94.5	31.2	24.00	24.00	197.1	274
Yearly Total	—	—	—	—	—	—	2302.2	—
Average	52.4	61.5	94	30.7	21.29	21.63	191.9	293

[1] No gas meter until July.

[2] 21 days.

was then noted in the room and was traced to the primary air mixing chamber. Attempts to adjust the burner eliminated the gas odor but resulted in repeated pilot failures. Further adjustments remedied the pilot trouble but resulted in poor heating efficiency. Due to extended illness of the manufacturer's field engineer, these difficulties were not completely overcome until he had occasion to visit the installation in April, 1947. Reference to Table I shows the greatly increased gas burning efficiency since that time. Occasional pilot failures still occur, but these are easily eliminated by adjustment of the pilot gas needle valve.

Probably the question uppermost in the minds of potential users of this or similar equipment is the one regarding the rapidity of sludge caking on the interior of the sludge heating coils. This problem has been found to be almost non-existent. The heater contains eight passes of 4-in. sludge heating pipe with a total length of 48 feet. To date only four of the passes have been in continuous use (26 months), two have seen 15 months service and the remaining two only 8 months service.

In April, 1948, all coils were given a thorough inspection. Only two of the four coils which had given continuous service showed evidence of incrustation. On these two a hard and brittle crust about $\frac{1}{32}$ inch in thickness was found. All other coils were clean. Because no difficulty has yet been experienced in maintaining the desired digester temperature, the two incrusted coils will not be cleaned until the fall of 1948. The time required for a thorough inspection of the sludge coils is less than one hour.

When the heater was first installed, a 10-in. stainless steel pipe was used to connect the forced draft fan to the brick chimney. While the cost of this pipe was high, it was nevertheless a minor part of the overall cost and its installation has proved to be a wise move. No evidence of corrosion has yet been found on it.

Prior to the first winter of operation some apprehension was felt concerning the possibility of maintaining sufficient heat in the small building (20 by 24 ft., one story with basement), because no means of heating was provided other than the heat exchanger. The poor adjustment of the gas burner during that winter caused excessive drafts, and inside temperatures occasionally dropped as low as 40° F. With better burner operation during the second winter, the lowest temperature noted was 50° F. This proved to be sufficient, since use of the building is limited to the pumping of sludge.

Maintenance of Digester Temperatures

During the first winter no attempt was made to carry a digester temperature higher than 90°. During that period it was found that by using only four sludge coils, temperatures in the water bath of the heater could be brought to 200° if desired, and more heat was thus available for the building. While this reduced the heat available for the digester, there was no radical reduction in tank temperature, the lowest monthly average being 87.5° F.

From October, 1947, to the present, an effort has been made to maintain a 95° temperature. Reference to Table I will show that this has been accomplished with ease, even in January, 1948, with the low monthly average

TABLE II.—Raw Sludge Data

Period	Inches Rainfall Per Month	Ave. M.G.D. Raw Sewage[1]	Raw Sludge Data					
			1000 Gal. Per Month	1000 Gal. Per M.G. Sewage	Ave. Dry Solids (%)	Ave. Vol. Solids (%)	1000 Lb. D.S. Per Month	1000 Lb. V.S. Per Month
Year Ending April 30, 1947								
Max. Month	6.85	5.91	374.1	9.46	6.09	81.6	141.0	100.0
Min. Month	0.15	0.75	170.0	2.60	3.64	71.0	58.1	45.3
Yearly Total	37.60	—	2634.3	—	—	—	1028.8	790.4
Average	3.13	1.95	219.5	5.69	4.76	77.1	85.7	65.9
Year Ending April 30, 1948								
Max. Month	9.38	2.80	200.1	4.23	7.02	80.4	117.0	83.6
Min. Month	1.26	1.30	157.6	2.01	4.59	65.0	69.1	54.0
Yearly Total	39.12	—	2121.4	—	—	—	1002.4	749.1
Average	3.26	1.82	176.8	3.36	5.65	75.1	83.5	62.4

[1] Does not include flow to Imhoff tanks.

TABLE III.—Digester Loadings and Gas Production

Period	Loading		Gas Production					
	Lb. D.S. Per C.F. Per Month	Lb. V.S. Per C.F. Per Month	Total 1000 C.F. Per Month	Ave. 1000 C.F. Per Day	Ave. C.F./Lb. Dry Solids	Ave. C.F./Lb. Vol. Solids	Ave. C.F./Cap. Contributing	Ave. C.F./S.F. Surface Per Day
Year Ending April 30, 1947								
Max. Month	4.83	3.33	1141.1	36.8	11.6	14.8	1.44	23.2
Min. Month	1.88	1.46	253.6[1]	14.9	6.5	8.3	0.69	9.4
Yearly Total	—	—	8388.7[2]	—	—	—	—	—
Average	2.81	2.15	699.1	24.3	8.6	11.2	1.15	15.3
Year Ending April 30, 1948								
Max. Month	3.75	2.68	886.8	28.6	10.7	13.8	1.30	18.0
Min. Month	2.21	1.76	652.0	21.0	6.6	9.3	0.94	13.2
Yearly Total	—	—	9247.1	—	—	—	—	—
Average	2.72	2.03	770.6	25.2	9.4	12.5	1.13	15.9

[1] Less than full month.

[2] Some months estimated.

air temperature of 22.8 degrees. During this period only six sludge coils have been in use.

Scum at the top periphery of the floating cover has never frozen. The lowest liquid temperature near that point was found to be 88° F. This uniformity is believed to be due to sludge recirculation and to discharge at the top center of the digester.

During January, with an average daily raw sludge addition of 5,600 gal. at 55.5°, the average hourly gas consumption by the heater was 368 cu. ft. This is only 55 per cent of the maximum heater capacity, and indicates that raw sludge additions could have been increased to 10,200 gal. daily, or that much lower outdoor temperature could have been experienced with no difficulty.

Though the control instruments installed with the heater are not extremely accurate, calculations made from the readings show that the heat exchanger efficiency is about 76 per cent. Efficiency would probably be greater with eight coils in operation. The readings also indicated that about 57 per cent of the heat exchanger output in January, 1948, was consumed by loss to the air and ground.

Incidental Notes on Digester Operation

During the 2 years most of the various operating routines have been used for short test periods, including trials of the several points of suction and discharge, and changes in circulation rate, in digester temperatures and in daily volumes of raw sludge. Since the fall of 1947 the system has been operated on the present plan, with the circulating pump operating at 140 g.p.m., drawing sludge from elevation 706.5, discharging to 713.0, digester temperature being held at 95° F., and raw sludge load taken from 40 per cent of the total flow to the plant.

The raw sludge loading has not been excessive, averaging about 2.75 and 2.10 lb. per cu. ft. per month in dry solids and volatile solids, respectively (Table III). The solids load, incidentally, has been calculated not on the basis of maximum digester capacity, but rather on the basis of average capacity (Table I), as determined from average floating cover elevations. During the time when various operating routines were tested there were many sudden and drastic changes in the loading applied to the digester.

The second year saw much less variation from the averages in all respects.

Gas production (Table III) has been abnormally high, averaging 9.4 cu. ft. per lb. dry solids and 12.5 cu. ft. per lb. volatile solids during the second year; per capita production averaged 1.13 cu. ft. per day. The gas activity per unit of surface area has been considerably greater than at most digester installations, having averaged 15.9 cu. ft. per sq. ft. of surface per day during the second year. This is equivalent to 0.82 cu. ft. of gas per cubic foot of tank (average capacity) per day.

The great gas activity has resulted in the production of a relatively poor supernatant liquid, or top sludge (Table IV), since it causes the solids of the tank to remain in almost constant suspension. The lower solids content during the first year was the result of having, for the first 6 months, a comparatively small quantity of solids in the digester. It was at first believed that the continued recirculation of sludge affected the supernatant quality, but extended test periods without recirculation disproved this theory. Since October, 1946, the supernatant has been dispersed in the four Imhoff tanks without greatly affecting their operation. There has therefore been no recycling of supernatant solids between the source of the raw sludge and the digester.

Experience with reference to gas activity has been considerably at variance with that of Sperry (2). It has been found that the degree of gas activity has no effect on the moisture content of the digested sludge. On the other hand, the moisture content and volatile solids content of the digested sludge show an increase when the per cent volatile solids in the raw sludge increases. It has also been noted that if a heavy solids content in the supernatant has no adverse effect on plant operation, gas activity can proceed at more than triple the rate mentioned by Sperry without any deleterious effect on the digested sludge.

The destruction of volatile matter has been exceptionally high, when calculated on the basis of 15 cu. ft. of gas being equivalent to 1 lb. of volatile matter. On this basis 82 per cent was destroyed during 1947–48. This is again at variance with the findings of Rankin (3) when taking into account the fact that the sludge detention

TABLE IV.—Supernatant and Digested Sludge Data

Period	Supernatant					Digested Sludge				
	Ave. Dry Solids (%)	Ave. Vol. Solids (%)	pH	1000 Lb. D.S. in Sup'n	1000 Lb. V.S. in Sup'n	1000 Gal. Per Month	Ave. Dry Solids (%)	Ave. Vol. Solids (%)	1000 Lb. Dry Solids	1000 Lb. Vol. Solids
Year Ending April 30, 1947										
Max. Month	3.33	66.9	7.4	51.9	32.1	93.5	6.95	60.8	35.2	18.5
Min. Month	0.32	52.1	6.9	5.0	3.6	0.0	2.96	48.1	—	—
Yearly Total	—	—	—	250.4	124.4[1]	343.7	—	—	147.3	77.8
Average	1.37	59.4	7.3	20.9	15.5	28.5	5.13	54.5	12.3	6.5
Year Ending April 30, 1948										
Max. Month	3.34	59.8	7.6	40.9	19.9	56.0	6.90	57.6	28.7	12.1
Min. Month	1.45	48.8	7.1	15.0	8.5	0.0	3.36	42.2	—	—[1]
Yearly Total	—	—	—	309.0	164.6	380.8	—	—	158.4	71.4
Average	2.16	54.0	7.4	25.8	13.7	31.7	4.97	51.6	13.2	6.0

[1] Not full year.

period in this digester averaged about 38 days, and that raw sludge volatile matter averaged 75.1 per cent.

Conclusions

1. The use of the outside heater and heat exchanger has proved to be one answer to the problems frequently posed by interior water coil heating of sludge digestion tanks.

2. The anticipated problem of sludge incrustation on heat exchanger coils has not been experienced; ease of inspection and ease of removing eventual incrustation has eliminated any fears in this regard.

3. Operating time involved is about the same, but operating costs are greater than with a gas boiler and interior coil installation, costs being roughly proportional to the increase in horsepower required.

4. Added benefits are received in greater solids reduction and gas production. It is realized that local conditions may be a factor in this result since the sewage received at Champaign-Urbana is almost entirely domestic in nature.

5. The high gas production results in a supernatant with high solids content.

6. The results in solids reduction suggest that continuous sludge recirculation and uniform temperatures cause a rate of digestion that is more rapid than in most installations.

References

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3. Rankin, R. S. "Digester Capacity Requirements." THIS JOURNAL, **XX**, 484 (1948).

ENGINEERS AND CONTRACTORS FORM JOINT COMMITTEE

With more economical construction as one of its major objectives, a National Joint Cooperative Committee has been established by the American Society of Civil Engineers and the Associated General Contractors of America.

The purpose of the new joint committee will be to recommend procedures in the public interest in fields where both organizations are mutually concerned. Subjects to be studied include:

Standard contract clauses for engineering construction clearly understandable by engineers and contractors.

Clear and definite specifications.

Design which can obtain maximum benefits from mechanized construction operations.

Equitable and clearly understandable bidding and awarding procedures for engineering construction.

Construction courses in engineering colleges to train men for construction.

Making work in construction and designing public works attractive to young engineers.

Three members will represent each organization on the Joint Committee which will hold its first meeting early this fall. Edmund A. Prentis, New York City, a national director of the ASCE, has been named chairman of the group to represent the civil engineers.

A STATISTICAL APPROACH TO SEWAGE CHLORINATION *

By Rolf Eliassen, Austin N. Heller and Herman L. Krieger

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Disinfection of sewage is commonly practiced by the addition of a water solution of elemental chlorine to the sewage before discharge into the receiving body of water. Since disinfection implies a decrease in the most probable numbers (M.P.N. per 100 ml.) of coliform bacteria, control of the process of chlorination at any sewage treatment plant must be directed toward achieving the desired M.P.N. in the effluent. Furthermore, since the test for the determination of the M.P.N. of coliform bacteria takes several days to complete, a working substitute for the M.P.N. test must be utilized. This test, or series of tests, must be a reliable index of the varying characteristics of sewage, and also be subject to close correlation with bacteriological results so that the control test will indicate the dosage of chlorine necessary to obtain the desired objectives in the disinfection process.

At many sewage treatment plants, control of chlorine dosage has been based primarily upon the maintenance of a stipulated chlorine residual after a specified period of contact between chlorine and sewage. In a study of the disinfectant action of chlorine on the effluent from the sewage treatment plant at Buffalo, N. Y., Symons (1) reported that ". . . . 0.1 p.p.m. of residual chlorine after 15 minutes contact is sufficient to produce the desired kill. . . ." Similarly, the New York State Department of Health (2) requires that "chlorine should be applied in such quantity that there will be a residual of at least 0.5 p.p.m., as determined by the orthotolidine test, after 15 minutes contact of chlorine with the sewage effluent." For certain types of receiving bodies of water this method of establishing arbitrary chlorine residuals may not be accurate enough to assure the achievement of the desired degree of disinfection at all times. Numerous investigators (3, 4, 5) have reported that dependence upon an arbitrary chlorine residual, such as 0.5 p.p.m., was not a reliable index of the expected density of coliform bacteria.

The question may rightfully be asked, "What expedient yardstick can be used to ascertain whether the desired kill has been achieved in a chlorinated sewage?" Standards of disinfection have been established by agencies such as the Interstate Sanitation Commission of the states of Connecticut, New York and New Jersey (1, 6). In its Pollution Abatement Compact, under Article VII, Section 1, it specified that, "All sewage discharged or permitted to flow into Class A waters of the district shall first have been so treated as . . . to effect a reduction of organisms of the B. coli group (intestinal bacilli) so that the probable number of such organisms shall not exceed one per cubic centimeter in more than fifty per centum (50%) of the samples of sewage effluent by the partially confirmed test; . . ." This standard is equivalent to an M.P.N. of 100 per 100 ml.

For the sewage treatment plant operator the important question is the relationship between this stipulated result and the dosage of chlorine. Will the maintenance of a chlorine residual

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of 0.5 p.p.m. after a 15 min. contact period be a reliable operating criterion? In ascertaining the reliability of this criterion, limitations of analytical procedures must first be examined.

With presently accepted techniques of sampling and examination for the M.P.N. (4, 5, 6) of coliform bacteria of sewage effluents, the question has been raised whether the magnitude of experimental error may not be such that reproducibility within reasonable limits cannot be expected in reporting on the results of treatment plant operation. Furthermore, the method used for the determination of residual chlorine in a sewage effluent may be subject to inherent limitations so that marked inconsistencies between bacteriological data and chlorine residuals may further disturb successful correlation.

When inherent shortcomings exist in analytical procedures, it is necessary to perform many experiments to overcome these shortcomings. Statistical methods of analysis must then be applied to the results of these experiments in order to achieve a more accurate correlation between groups of bacteriological and chemical data.

The objectives of this paper are to determine by accepted methods of statistical analysis:

1. The effect of initial mixing of chlorine and sewage on the killing of coliform bacteria.

2. The effect of initial mixing on the M.P.N. of coliform bacteria in unchlorinated sewage.

3. The effect of variations of chlorine dosage on the killing of coliform bacteria.

4. The application of the chlorine demand test to control chlorine dosage and to serve as a reliable index of the stipulated density of coliform bacteria which will remain in the chlorinated sewage.

5. The application of the chlorine residual test to control chlorine dosage and to serve as a reliable index of the stipulated density of coliform bacteria which remain in the chlorinated sewage.

Experimental Procedure

In all of the chlorination experiments herein reported the sewage utilized was obtained from one of the sewers of the Borough of the Bronx. This was a weak domestic sewage, with a B.O.D. averaging 120 p.p.m. and a chlorine demand of about 5 p.p.m. Before chlorination, the raw sewage was filtered through non-absorbent cotton to remove the larger suspended particles and to simulate settled sewage. Filtering the sewage in this manner did not reduce the coliform organisms substantially, but did present a more uniform medium for the experimental work which followed.

The chlorination agent was a freshly prepared stock solution of elemental chlorine dissolved in water with a strength of 1,000 p.p.m. of available chlorine. For each day's sewage studied a 10-min. chlorine demand was determined. For all of the disinfection experiments a contact period of 10 min. was employed. Chlorine residuals were determined in all cases by the orthotolidine method.

Since a study of the effect of initial mixing of sewage and chlorine was one of the principal objectives of this research, most of the experiments were performed on triplicate 500-ml. portions of the cotton-filtered Bronx sewage. One portion was given an initial rapid mix of chlorine solution and sewage for 15 sec. with a Hamilton Beach Electric Mixer, Model 25; the second portion was subjected to a slow manual mix with ten stirs of a glass rod at approximately 100 r.p.m.; and the third portion received no agitation after the addition of chlorine solution.

The sewage was chlorinated in most cases to 40, 70, 100, 140 and 200 per cent of the chlorine demand. At the end of a 10-min. contact period, 50-ml.

portions were withdrawn aseptically by means of a pipette and placed into sterile bottles containing 0.5 ml. of a 10 per cent solution of sodium sulfite to arrest the action of chlorine. Residual chlorine determinations were made on all samples which had been chlorinated to or beyond 100 per cent of the chlorine demand.

The most probable number (M.P.N.) of coliform bacteria per 100 ml. of the chlorinated sewage was determined by the partially confirmed test, unless otherwise noted. Brilliant green lactose bile broth was used as the confirmatory medium. In each sample of unchlorinated sewage used as a control, the M.P.N. was determined by direct planting into brilliant green lactose bile broth. All M.P.N. determinations were made on the basis of four dilutions, using three tubes for each dilution.

Number of Experiments Required for Statistical Significance of M.P.N. Data

Before embarking on the experimental work which comprises the main body of this paper, it was necessary to ascertain the number of individual experiments needed in each series of experiments performed under similar conditions to permit valid conclusions to be drawn. It was also necessary to establish the most desirable procedure of sampling for bacteriological analysis, in order to eliminate the effect of experimental errors in arriving at conclusions.

From the standpoint of expediency it would have been desirable if one experiment would have sufficed for each chosen chlorine dosage and for each type of mixing of chlorine solution and sewage. Furthermore, it would have been a simple procedure if only one 50-ml. portion were extracted from each sample for bacteriological analysis. If valid results could be achieved by this simple procedure, direct interpretation would be possible without resort to statistical methods of analysis.

In order to ascertain whether such a procedure would be justified, four series of experiments were performed, each with a specific dosage in terms of chlorine demand. The dosage for each series was equivalent to 40, 100, 140, and 200 per cent, respectively, of the chlorine demand of the sewage used in each experiment. Ten experiments were performed in each series on sewage taken from a large Bronx sewer on ten separate days. This procedure took account of variations in sewage characteristics from day to day. Initial rapid mixing for 15 sec., followed by a contact period of 10 min., was used for each experiment. On each day of the experiments, an unchlorinated control sample was also subjected to mixing and a 10-min. holding period before sampling. The results of these experiments are presented in Table I.

Examination of this table reveals that an increase in the consistency of results is obtained with increasing dosages of chlorine and consequent decreases in the numbers of coliform bacteria surviving in the sewage. In the

TABLE I.—Fluctuations of M.P.N. of Coliform Bacteria at Various Chlorine Dosages

Experiment Number	M.P.N. of Coliform Bacteria per 100 Ml. for Indicated Percentages of Chlorine Demand Satisfied				
	0%	40%	100%	140%	200%
1	2.5 M	450 T	40	40	9
2	250 T	450 T	2500	70	4
3	95 T	45 T	2500	40	<2.2
4	250 T	450 T	2500	90	<2.2
5	950 T	250 T	250	40	<2.2
6	450 T	25 T	9500	450	<2.2
7	2.5 M	95 T	2500	250	4
8	450 T	25 T	4500	250	<2.2
9	950 T	45 T	250	40	<2.2
10	45 M	95 T	250	25	<2.2
Maximum	45 M	450 T	9500	450	9
Minimum	95 T	25 T	40	25	<2.2
Mean of $Logs_{10}$	5.95	5.04	3.00	1.91	0.22

Note: M = million, T = thousand.

unchlorinated control samples, the range of M.P.N. values extends from 95 thousand to 45 million. With sewage chlorinated to 100 per cent of the chlorine demand the range was from a minimum of 40 to a maximum of 9,500. At 200 per cent of the chlorine demand, the dispersion of results had narrowed to a range of from less than 2 to 9 coliform bacteria per 100 ml. of sample.

From these inconsistencies in results it is evident that it would not be possible to secure a valid interpretation if only one experiment was performed at each dosage and a single portion of sewage was withdrawn for analysis.

From the values of the mean logarithm M for each of the series presented in Table I, it is apparent that there is some grouping of data at each of the chlorine dosages. In order to evaluate the significance of grouped data, with the dispersions noted in Table I, it would be necessary to employ statistical methods of analysis. The methods which can be employed are fundamental in nature and are described in any standard textbook on statistical methods (7). For the sake of clarity, the statistical methods of analysis to be utilized in this paper will be outlined briefly in the Appendix.

Since the withdrawal of only one portion from one experiment did not give consistent bacteriological results, the next step was to investigate the accuracy of analyzing three portions of sewage from one experiment. Two series of ten experiments were performed by chlorinating Bronx sewage to 100 per cent of the chlorine demand. For the first series an initial rapid mix was used and triplicate 50-ml. portions were withdrawn for M.P.N analysis. For the second series an initial slow mix was given the chlorine and sewage. Only one portion was withdrawn for analysis from each of the ten experiments in the slow mix series.

TABLE II.—Comparison of Statistical Significance of using Three Portions of One Experiment Versus One Portion of Ten Experiments

Experiment Number	Mean Log of M.P.N.[1]		σ_D	$\frac{D}{\sigma_D}$
	Rapid Mix	Slow Mix		
(1)	(2)	(3)	(4)	(5)
1	3.64	3.49	0.269	+ 0.56
2	3.59		0.156	+ 0.58
3	1.54		0.183	− 9.7
4	4.48		0.058	+17.2
5	4.28		0.115	+ 6.6
6	3.40		—	—
7	4.22		0.365	+ 2.9
8	4.57		0.082	+ 1.3
9	3.76		0.082	+ 3.3
10	4.12		0.112	+ 5.6
Mean of 10 Experiments	3.76	3.49	0.269	+ 1.3

[1] Col. (2) represents mean log of M.P.N. of three successive portions; Col. (3) represents mean log of M.P.N. of one portion, ten experiments.

Table II presents a statistical analysis of the data obtained in these two series of experiments. Column 2 represents the mean of the logarithms of the M.P.N. per 100 ml. of coliform bacteria found in the three successive portions of each experiment in which rapid mixing was employed. Each value in Column 3 is the mean of the logarithms of the ten M.P.N. values obtained by analyzing one portion from each of the ten slow-mix experiments.

The reason for employing the mean logarithmic value for the slow-mix results was to obtain a valid base for statistical comparison of the data obtained in each experiment. Thus, the mean $\log_{10}$ for three successive portions in each experiment will be compared with a common base value from ten experiments. It will be proven later that there is no significant difference between slow and rapid mixing so that comparisons utilized in Table II

can be presumed to be statistically valid.

Column 4 shows the values of σ_D, the standard error of the difference between the two series of results in Columns 2 and 3. D/σ_D in Column 5 represents the test for the significance of the differences noted in Columns 2 and 3. As explained in the Appendix outlining statistical methods, values of D/σ_D (Column 5) greater than 2.5 indicate that the results are significantly different.

If the method of analyzing three portions of one experiment, using four dilutions and three tubes for each dilution to determine the M.P.N. of coliform bacteria, were statistically valid, all of the results in Column 5 should be consistently above or below a value of 2.5. Table II indicates that the values in Column 5 are far from consistent. Five values are greater than + 2.5; one is greater numerically than − 2.5; and four are less than 2.5. As stated previously, a number of experiments to be presented later will show that no significant difference exists in the results obtained from rapid and slow initial mixing. Therefore, the values in Column 5 should all be in the range from + 2.5 to − 2.5. Only four values are in this range, namely those from Experiments 1, 2, 6 and 8. Therefore, under the conditions of these experiments, three portions taken for analysis from only one experiment give insufficient data from which valid conclusions may be drawn.

If the comparison was made by comparing the mean of ten experiments using rapid mix against three portions from each of ten experiments with slow mix, the same inconsistencies would be noted. Regardless of the basis for comparison, three portions from only one experiment will not yield consistent results which will permit the correlation of bacteriological and chemical data.

The principal factors contributing to these inconsistencies are:

(1) Heterogeneity of the sewage and difficulty of obtaining a representative sample;

(2) The use of four dilutions, with three tubes for each dilution, being insufficient for desired precision; and

(3) The unreliability of the chlorine demand test as a control of chlorine dosage, using orthotolidine as an indicator.

In order to balance out the effect of any experimental errors introduced by the above factors, a sufficient number of experiments will have to be performed and the results analyzed by statistical methods. On the basis of the laws of probability it is possible to distinguish between differences in results due to chance alone, such as experimental errors inherent in analytical techniques, and the differences in results due to major environmental factors involved in the conduct of experiments.

With this in mind, the authors attempted to evaluate the consistency of results which could be obtained through the use of ten separate experiments for each series, taking one 50-ml. portion for bacteriological analysis from each experiment. The results obtained through the use of this procedure are presented in the last line of Table II. Column 2 is the mean of the logarithms of the M.P.N. values from three portions of each of the ten experiments in which rapid mixing was employed. As explained previously, Column 3 already is the mean of the logarithms of the ten results using slow mix. From Column 5 it will be noted that the test of significance has a value of + 1.3. This indicates that there is no significant difference between rapid and slow mixing on the basis of the results of ten experiments, with one portion withdrawn for analysis from each experiment. Later results will indicate the consistency of values of the test of significance using ten experiments.

Before adopting this as a standard procedure for the chlorination experiments, it was desirable to determine whether any advantages would accrue from the analysis of three portions from each of ten experiments instead of only one portion as cited above. Three series of chlorination experiments were performed in this phase of the investigation. The controlling factor in each of the three series was the type of initial mixing employed. Chlorine dosages were proportioned to satisfy 40, 70 and 100 per cent of the chlorine demand for the sewages which were obtained from the Bronx sewers on ten separate days. Unchlorinated controls were also run on each day. Ten separate experiments were run at each chlorine dosage and with each type of mixing. Three 50-ml. portions were withdrawn for bacteriological analysis in each experiment.

Table III presents a summary of the results obtained, together with a statistical analysis to determine the significance of the results. Column 2 represents the mean logarithms of the M.P.N. values of the first portion withdrawn for bacteriological analysis from each of ten experiments. Column 3 represents the mean logarithm of the second portion withdrawn from each of the ten experiments comprising the series. The M.P.N. values fell into Column 2 or Column 3 entirely by chance, thus permitting statistical analysis of the data in each of the columns.

Column 4 represents the standard error (σ_D) of the difference between the results of Columns 2 and 3. Column 5 is the measure of significance of these differences for the various chlorine dosages in each of the three series. It is of considerable interest to note that D/σ_D in all instances was much less than the significant value of 2.5. Irrespective, therefore, of the type of initial agitation of chlorine and sewage, and the dosage of chlorine in relation to the chlorine demand up to 100 per cent, the mean value of the M.P.N. of coliform bacteria per 100 ml. of sewage examined from the first portion of each of ten experiments did not differ significantly from the mean value of the M.P.N. in the second portion. Although not shown in Table III, similar results were obtained from the third portion examined and compared with the first portion.

Therefore, a basis has been established upon which evaluations will be made in succeeding sections of this paper of the various factors involved in the chlorination of sewage and its control. This basis involves the performance of ten separate experiments under similar conditions on ten separate samples of sewage. One 50-ml. portion is withdrawn from each experiment for the determination of the M.P.N. of coliform bacteria using four dilutions, with three tubes for each dilution. This procedure has been shown to yield results which are consistent and which may be analyzed by statistical methods.

TABLE III.—Statistical Significance of M.P.N. Determinations on One Portion for Ten Separate Experiments at Various Chlorine Dosages

Type of Initial Mixing	Per Cent Chlorine Demand Satisfied	Mean Log of M.P.N.		σ_D	$\frac{D}{\sigma_D}$
		First Portion	Second Portion		
	(1)	(2)	(3)	(4)	5)
Rapid	0	5.51	5.48	0.117	0.32
	40	4.58	4.63	0.147	0.80
	70	3.79	3.82	0.105	0.84
	100	3.79	3.65	0.166	1.3
Slow	0	5.31	5.26	0.147	1.1
	40	4.48	4.45	0.130	1.3
	70	3.99	4.00	0.170	0.72
	100	3.55	3.53	0.125	0.91
No Mix	0	5.17	5.23	0.108	1.1
	40	4.46	4.40	0.098	0.93
	70	3.88	3.95	0.082	1.1
	100	3.63	3.62	0.101	0.88

Effect of Initial Mixing on Coliform Reduction

Chlorination, as usually practiced at sewage treatment plants, involves the addition of a solution of chlorine to sewage as it flows into a chlorine contact chamber or a long outfall sewer. In most cases, no attempt is made to provide for any special mixing of the chlorine solution and sewage.

It should be emphasized that mixing of chemicals with the liquids is standard practice prior to the coagulation of water and sewage. Marked increases in the effectiveness of coagulant chemicals have been noted when proper mixing devices, either hydraulic or mechanical, have been employed. It may well be asked why it is not equally important to provide for intimate mixing of chlorine solution with the sewage to be treated in order to secure a thorough dispersion of chlorine and to permit its uniform action throughout the mass of sewage.

The answer to this question will be found in the results presented in this paper. An indication of the answer was also given in a comprehensive survey of the field of sewage chlorination by Rudolfs and Gehm (8). The indications in that survey, however, were not followed up by other experimenters to the point where conclusive proof of the value of mixing could be derived from the results of experimental work.

The authors of this present paper will endeavor to submit conclusive proof of the need for mixing devices ahead of the chlorine contact chamber. This proof will be based on the results of many experiments, together with statistical analysis of these results. This should be of interest to designing engineers and plant operators, as well as state agencies which formulate design and operating standards for sewage treatment plants.

In accordance with the experimental procedure outlined in previous sections of this paper, many experiments were performed on the chlorination of Bronx sewage using two types of initial mixing. Table IV presents a summary of the results of these experiments, and a comparative analysis of the effect of rapid vs slow mix, rapid vs no mix, and slow vs no mix.

TABLE IV.—Statistical Significance of the Effects of Initial Mixing on the M.P.N. of Coliform Bacteria at Various Chlorine Dosages

Types of Mixing under Comparison	Per Cent Chlorine Demand Satisfied	Mean Log of M.P.N.		σ_D	$\frac{D}{\sigma_D}$
		Type of Mix	Type of Mix		
	(1)	(2)	(3)	(4)	(5)
		Rapid	Slow		
	0	5.95	5.84	0.184	+ 0.56
Rapid	40	5.04	4.91	0.084	+ 1.5
vs	100	3.00	3.08	0.086	− 0.83
Slow	140	1.91	1.90	0.085	+ 0.06
	200	0.43	0.40	0.077	+ 0.3
		Rapid	No Mix		
	0	5.95	5.87	0.158	+ 0.53
Rapid	40	5.04	5.24	0.087	− 2.3
vs	100	3.00	4.29	0.237	−>2.5
No Mix	140	1.91	3.54	0.104	−>2.5
	200	0.43	2.34	0.193	−>2.5
		Slow	No Mix		
	0	5.84	5.87	0.148	− 0.15
Slow	40	4.91	5.24	0.137	− 2.4
vs	100	3.08	4.29	0.206	−>2.5
No Mix	140	1.90	3.54	0.141	−>2.5
	200	0.40	2.34	0.178	−>2.5

Before discussing the comparative effects of mixing it should be observed in Table IV that each of the series employed unchlorinated control samples which were subjected to similar mixing as the chlorinated samples. It should also be observed that mixing produced no significant difference in the M.P.N. of coliform bacteria of unchlorinated sewage, as may be noted in the last column of Table IV opposite each of the lines marked "0" per cent chlorine demand satisfied. The D/σ_D for rapid vs slow mix was + 0.56; for

rapid vs no mix, + 0.53; and for slow vs no mix, − 0.15. All of these values are considerably less than 2.5. Therefore, it may be stated that each of the series of experiments was performed on sewage samples having approximately equal values of M.P.N. of coliform bacteria. It may also be stated that mixing had no significant effect on M.P.N. values detected in unchlorinated Bronx, cotton-filtered sewage.

The first section of Table IV presents a statistical comparison of rapid vs. slow mix. It will be noted that when sewage was chlorinated to 40, 100, 140 and 200 per cent of the chlorine demand, no significant difference was observed in the densities of coliform bacteria surviving after a contact period of 10 minutes.

In the second section of Table IV the comparison is between rapid mix and no mixing of chlorine solution and sewage. With chlorine dosages at or above 100 per cent of the chlorine demand, significant differences were noted, with mixing giving much lower values of the M.P.N. of coliform bacteria surviving. The same holds true for the results in the third section of Table IV. It is evident that the same trend persists at 40 per cent of the chlorine demand satisfied, where the test of significance shows a value of − 2.3 for rapid vs no mix and − 2.4 for slow vs no mix. The latter results are very close to the accepted value of significance of 2.5, yet the difference may not be great enough to be consistently significant.

From the results presented in Table IV it is evident that mixing of chlorine solution and sewage is important in securing the greatest kill of coliform bacteria. The type of mixing is not as significant as the need for short-period mixing of some sort, whether it be a mechanical device to give rapid mixing or a hydraulic device to produce sufficient turbulence to disperse the chlorine throughout the sewage.

Effect of Initial Mixing on Chlorine Demand Requirements to Reach a Stipulated M.P.N. Value

Further evidence of the effectiveness of initial rapid or slow mixing may be derived from a different method of analysis of the results of the previous experimental work. As stated in the introduction to this paper the ultimate yardstick of chlorine dosage requirements should be the M.P.N. of coliform bacteria per 100 ml of the chlorinated sewage. Two M.P.N. values frequently cited by stream pollution control authorities are 300 per 100 ml. and 100 per 100 ml.

On the basis of the many experiments performed at various chlorine dosages, the observed M.P.N. values

TABLE V.—Significance of Initial Mixing on Chlorine Requirements to Reach a Coliform Index of 300 or Less Per 100 Ml.

Per Cent Chlorine Demand Satisfied	Ratio of Observations with M.P.N. 300 or Less, to Total Number of Experiments			Chi-Square	Significance
	Rapid	Slow	No Mix		
0	0/40	0/40	0/40	<5.0	No
40	0/30	0/30	0/30	<5.0	No
70	2/10	2/10	1/10	<5.0	No
100	6/40	6/40	2/40	<5.0	No
140	15/30	13/30	0/30	>5.0	Yes
180	10/10	9/10	3/10	>5.0	Yes
200	29/30	29/30	19/30	>5.0	Yes

less than 300 were tabulated. A summary of the results obtained is presented in Table V. The numerator of each fraction signifies the number of times values less than 300 were observed; the denominator signifies the total number of experiments under each classification of mixing and dosage in proportion to chlorine demand. The chi-square test was applied to determine the significance of the differences in values obtained between mixing and no mixing. The results of rapid and slow mixes were combined, since previous statistical analysis showed these to be similar in effect. Chi-square values greater than 5.0 were considered significant, based on the laws of probability.

It will be noted in Table V that for chlorine dosages at or greater than 140 per cent of the chlorine demand the results were overwhelmingly in favor of mixing. At 140 per cent of the chlorine demand, mixing induced kills to M.P.N. values below 300 in 28 out of 60 experiments, or 46.6 per cent of the time, as compared to none out of 30 experiments for no mixing. Similarly, at 180 per cent of the chlorine demand mixing showed 19 out of 20 values below 300, or 95 per cent, as opposed to 3 out of 10, or 30 per cent for no mixing. A significant difference was still apparent at 200 per cent of the chlorine demand. Table VI shows that similar results were obtained at a stipulated coliform index of 100 per 100 ml.

In order to achieve a stipulated coliform index of 300 per 100 ml. approximately 50 per cent of the time on Bronx sewage, Table V shows that it would be necessary to dose the sewage to approximately 140 per cent of the chlorine demand if initial thorough mixing were provided. With no mixing, the dosage would have to be 190 to 200 per cent of the chlorine demand. Thus, a marked saving in the cost of chlorine could be accomplished through the use of initial mixing of chlorine solution and sewage.

Relationship Between Chlorine Dosage and M.P.N. of Coliform Bacteria Surviving

At a number of sewage treatment plants the practice is to establish a fixed dosage of chlorine in parts per million, proportioned only according to flow.

TABLE VI.—Significance of Initial Mixing on Chlorine Requirements to Reach a Coliform Index of 100 or Less Per 100 Ml.

Per Cent Chlorine Demand Satisfied	Ratio of Observations with M.P.N. of 100 or Less, to Total Number of Experiments			Chi-Square	Significance
	Rapid	Slow	No Mix		
0	0/40	0/40	0/40	<5.0	No
40	0/30	0/30	0/30	<5.0	No
70	0/10	0/10	0/10	<5.0	No
100	2/40	2/40	1/40	<5.0	No
140	7/30	6/30	0/30	>5.0	Yes
180	7/10	7/10	3/10	4.8	Probable
200	27/30	28/30	12/30	>5.0	Yes

Such a practice does not take account of variations in chlorine demand of the sewage or residual chlorine in the sewage after the period of contact. The data presented in this paper can be analyzed by statistical methods to evaluate the effectiveness of such a practice.

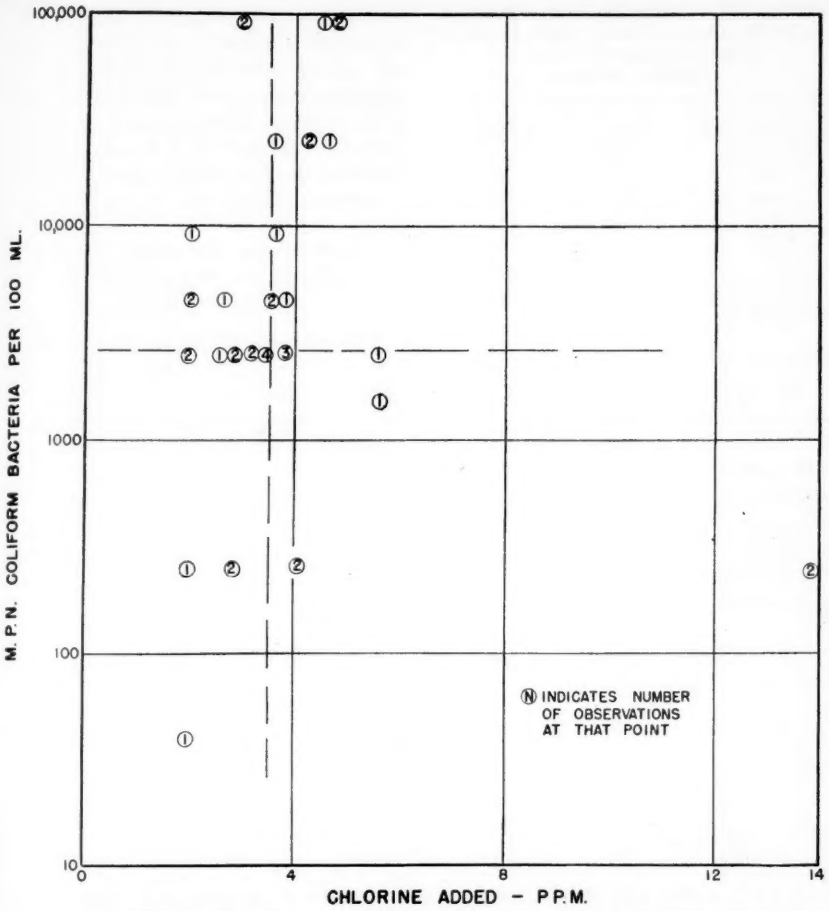

FIGURE 1.—M.P.N. vs. chlorine at 100 per cent chlorine demand.

Figure 1 summarizes the results of the M.P.N. of coliform bacteria surviving when Bronx sewage was dosed with chlorine to 100 per cent of the chlorine demand. The M.P.N values are plotted on a logarithmic scale against the parts per million of chlorine added to satisfy 100 per cent of the chlorine demand of each day's sewage. It is immediately apparent that the M.P.N. results are widely scattered, ranging from 40 to 100,000 coliform bacteria per 100 ml. of chlorinated sewage. No direct relationship was evident between the M.P.N. and the dosage of chlorine.

Further evidence of the lack of correlation between coliform index and chlorine dosage is revealed by the application of the "small" chi-square test for statistical significance. As explained in the Appendix, when this test is applied to a series of observations such as those represented by Figure 1, a value greater than 6.0 is considered significant. By plotting graphs for dosages of chlorine to satisfy 40, 140 and 200 per cent of the chlorine demand similar to Figure 1, which represents 100 per cent of the chlorine demand, and constructing median axes

TABLE VII.—Test of Significance Between P.P.M. Chlorine Dosage and Coliform Index at Various Per Cents of Chlorine Demand

Per Cent Chlorine Demand Satisfied	Small Chi-Square	Significance
40	3.4	No
100	3.4	No
140	5.0	No
200	0.2	No

Note: The observations were made on initial rapid and slow mixing only.

as shown by the dotted lines in Figure 1, the values of "small" chi-square were obtained for each series.

These values are presented in Table VII. Since all of the results were below 6.0, no significance is indicated. This means that the M.P.N. of coliform bacteria remaining in Bronx sewage after chlorination and a 10-min. contact period has no direct relationship to the chlorine dosage. In other words, the establishment of an arbitrary dosage of chlorine to be added to the sewage, proportioned only according to flow, is not a reliable means of achieving a stipulated M.P.N. of coliform bacteria in the effluent from a sewage treatment plant.

Relationship Between Chlorine Residuals and M.P.N. of Coliform Bacteria

Chlorination of sewage to a specific chlorine residual after a stipulated period of contact is common practice in many sewage treatment plants in accordance with the requirements of a number of state health departments. On the basis of the experimental work herein reported, it is possible to evaluate the effect of chlorine residuals on the M.P.N. of coliform bacteria after a 10-min. contact period. The results

TABLE VIII.—Relation Between Chlorine Residual and Coliform Index

Expt. No.	Per Cent Chlorine Demand Satisfied											
	140%						200%					
	Rapid		Slow		No Mix		Rapid		Slow		No Mix	
	Chl. Res.	M.P.N.	Chl. Res.	M.P.N.	Chl. Res.	M.P.N.	Chl. Res.	M.P.N.	Chl. Res.	M.P.N.	Chl. Res.	M.P.N.
1	0.5	2500	0.4	25T	0.4	25T	1.2	9	1.0	250	0.75	2500
2	0.4	4500	0.3	950	0.35	25T	1.4	25	1.2	25	1.4	1100
3	0.5	2500	0.35	25T	0.4	45T	1.2	<2.2	1.2	95	1.0	450
4	0.6	250	0.4	4500	0.5	250T	1.5	<2.2	1.4	45	1.4	450
5	0.5	150	0.4	250	0.5	1500	1.2	<2.2	1.2	<2.2	1.4	45
6	0.6	250	0.5	250	0.5	4500	1.5	<2.2	1.2	9	1.4	1400
7	0.4	950	0.35	9500	0.5	95T	1.4	<2.2	1.2	450	1.4	2500
8	0.5	4500	0.5	950	0.6	95T	1.5	9	1.2	25	1.4	950
9	0.5	450	0.5	250	0.6	4500	1.2	<2.2	1.4	<2.2	1.6	250
10	0.6	450	0.4	250	0.5	9500	1.5	<2.2	1.2	<2.2	1.4	95
11	0.6	40	0.35	25	0.6	9500	1.6	9	1.4	<2.2	1.6	40
12	0.6	70	0.35	<2.2	0.6	4500	1.2	4	1.0	<2.2	1.4	2500
13	0.5	40	0.35	25	0.6	9500	1.2	<2.2	1.2	<2.2	1.4	40
14	0.6	40	0.35	<2.2	0.6	4500	1.4	<2.2	1.0	<2.2	1.4	450
15	0.35	450	0.5	40	0.75	250	1.4	<2.2	1.6	4	1.6	250
16	0.6	250	0.35	250	0.4	9500	1.6	4	1.4	<2.2	1.6	250
17	0.5	250	0.6	250	0.75	2500	1.2	<2.2	1.2	9	1.6	450
18	0.8	40	0.35	450	0.5	9500	1.4	<2.2	1.4	<2.2	1.6	450
19	0.5	25	0.75	90	1.0	2500	1.2	<2.2	1.2	<2.2	1.4	45
20	0.5	90	0.5	25	0.75	450	1.2	<2.2	1.2	<2.2	1.2	250

Note: T = thousand.

of chlorine residual determinations, together with the corresponding values of M.P.N. for each experiment, are shown in Table VIII. These results were obtained when chlorinating Bronx sewage to 140 and 200 per cent of the chlorine demand, and with or without initial mixing, as indicated in Table VIII.

Using an M.P.N. value of 300 coliform bacteria per 100 ml. as a stipulated criterion of effluent quality, a statistical breakdown of the data in Table VIII was performed. The basis for the breakdown was the per cent of time that the M.P.N. at specific chlorine residuals was less than the selected value of 300. Rapid mix and slow mix results were combined because previous statistical analyses indicated no significant differences in results with either type of initial mixing. The results of this analysis of the data are presented in Table IX and in Figure 2.

TABLE IX.—Effect of Mixing on the Incidence of an M.P.N. of 300 or Less at Various Chlorine Residuals

Chlorine Residual (p.p.m.)	Per Cent of Total Observations with M.P.N. of 300 or Less per 100 Ml.	
	Mixing	No Mixing
0.4	29	0
0.5	43	0
0.6	64	0
0.75	87	0
1.1	100	50
1.4	—	56
1.6	—	72

These results present the key to the most logical method for the control of chlorine dosage in a sewage treatment plant. It must first be conceded that the ultimate yardstick of disinfection should be the M.P.N. of coliform bacteria in the effluent, depending upon

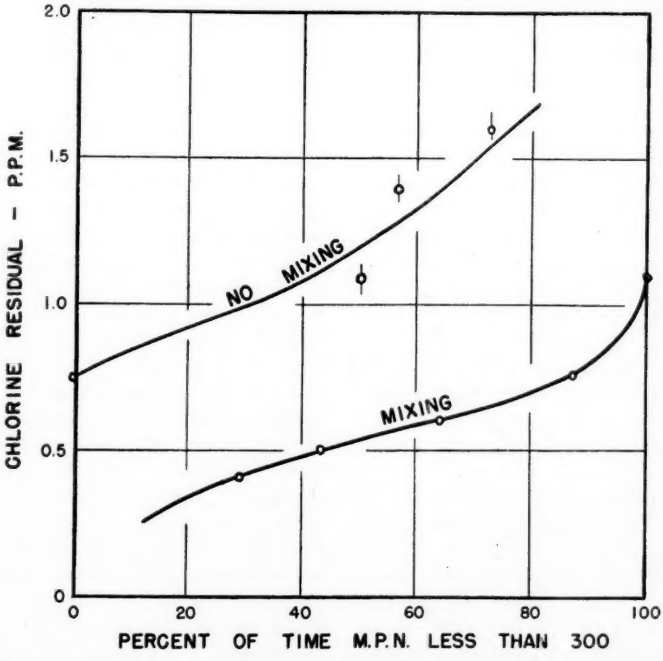

FIGURE 2.—Relationship between chlorine residual and M.P.N. of coliform bacteria, with and without initial mixing.

the requirements called for by the receiving body of water. Whether these requirements be 100 coliform bacteria per 100 ml. in 50 per cent of the analyses, as specified by the Interstate Sanitation Commission, or 300 per 100 ml., as selected for Figure 2, some value should be stipulated by a regulatory agency if disinfection is to be required or recommended.

From the results in Figure 2 it is evident that in order to achieve a bacterial kill sufficient to yield M.P.N. values at or below 300 per 100 ml. 50 per cent of the time, it would be necessary to chlorinate Bronx sewage to maintain a residual of 0.55 p.p.m. after a 10-min. contact period. This is predicated upon the use of initial mixing of chlorine solution and sewage. On the other hand, if no initial mixing were provided, it would be necessary to maintain a residual of 1.1 p.p.m., or twice that necessary with mixing. This illustrates most strikingly the advantages to be gained by the use of initial mixing, as previously proven by statistical methods of analysis of other data.

By adopting the same technique of analysis for chlorine residuals and coliform indices, it would be possible to establish the chlorine residual necessary to reach any stipulated M.P.N. in any sewage treatment plant effluent. The frequency of occurrence selected can be any reasonable value, but 50 per cent of the time is a logical frequency based on expediency and on such a heterogenous medium as sewage.

Application to Plant Scale Operation

Consideration must be given to the possibility of translating these results from the scale of laboratory experiments to conditions existing at sewage treatment plants. Many of the factors discussed in the first sections of this paper apply equally well to laboratory and plant scale procedures. These include the methods of sampling, number of samples to minimize the effects of experimental errors, procedures for bacteriological determinations, and statistical analysis for correlation between chemical and bacteriological results.

Differences between laboratory techniques and plant practices may become more significant when comparing certain types of mixing at the point of chlorine addition to sewage. Rapid mixing, as employed in the laboratory, can probably be considered to simulate a high-speed mechanical mixing device in a treatment plant. Therefore, it may be presumed that results can be interpreted directly from laboratory to plant scale performances with rapid mixing.

Slow mixing in the laboratory experiments involved stirring the contents of a beaker slowly by means of a glass rod, thus inducing turbulence in the liquid. This same degree of turbulence, if produced in a pipe or channel at the point of chlorine addition, should be equally effective as a means of mixing chlorine solution and sewage and attaining the desired bactericidal efficiency of chlorine.

Many treatment plants may have adequate turbulence following a Venturi flume, or in a pipe line or channel in which velocities are maintained at a high value for an appreciable distance. Evaluation of the effectiveness of such mixing in an actual plant is beyond the scope of this paper and must be determined by observations and the correlation of chemical and bacteriological analyses at each particular plant. By further laboratory investigations it may be possible to develop a mathematical relationship among the degree of turbulence as measured by Reynolds' Number, the time during which this turbulence persists after the addition of chlorine to the sewage, and the efficiency of disinfection.

In contrast to plants where rapid or slow mixing takes place, many treat-

ment plants practice the addition of chlorine solution to sewage at the entrance to the chlorine contact chamber. Velocities in the usual types of chambers are generally so low that the degree of turbulence is not sufficient to induce the desired mixing. This is the type of plant in which disinfection results might be presumed to correspond to those obtained in the experimental work in the "no-mixing" category. These relatively unsatisfactory disinfection results can be improved by the introduction of chlorine solution to the sewage at a point where greater turbulence exists, or where it can be provided by baffling or some other hydraulic or mechanical means. The object is to secure uniform distribution of chlorine throughout the sewage before it reaches the contact chamber so that maximum disinfection may be attained.

Another practical application which may be derived from the disclosures in this paper is the prediction of the chlorine residual which must be maintained at any sewage treatment plant in order to achieve a stipulated M.P.N. of coliform bacteria in the chlorinated effluent. The method to be employed is similar to that used in obtaining the results in Table VIII. On ten separate days grab samples should be taken of the effluent from the final stage of the plant prior to chlorination. Chlorine demand tests should be run on each of the samples. On each day the sewage should be divided into four 500-ml. portions, and sufficient chlorine should be added to satisfy 120, 140, 160 and 180 per cent of the chlorine demand. This will assure a wide enough variance of chlorine residuals. A uniform mix with a glass stirring rod should be given each chlorinated sample. After the desired period of contact, corresponding to the average detention time in the contact chamber, the sewage should be analyzed for the M.P.N. of coliform bacteria and chlorine residuals in accordance with methods previously established in this paper.

The results of chlorine residuals and M.P.N. values should then be tabulated and grouped according to chlorine residuals found in each portion. Following this, a value of M.P.N. of coliform bacteria should be selected as the desired measure of disinfection, such as the M.P.N. value of 300 per 100 ml. used in Table IX. A table similar to Table IX can then be formed on the basis of the percentage of samples in which the M.P.N. values are less than the value selected above at each value of chlorine residual. Finally, a graph similar to Figure 2 can then be plotted. From this graph, the chlorine residual necessary to obtain the desired M.P.N. results any chosen per cent of the time can then be obtained. This permits the chlorination process in any sewage treatment plant to be controlled by a rational method.

Summary and Conclusions

The objectives of this paper have been to apply statistical methods of analysis to the investigation of certain phases of the process of disinfection of sewage, particularly the effect of initial thorough mixing on the bactericidal efficiency of chlorine. It was also desired to develop a rational basis for the control of the chlorination process in any sewage treatment plant. Before these objectives could be achieved, it was necessary to establish a statistically valid basis for the evaluation of experimental results. Using Bronx cotton-filtered sewage and determining M.P.N. values on the basis of four dilutions in triplicate, it was shown that performing one chlorination experiment and analyzing one portion for its coliform index gave erratic results. Similarly, the performance of one experiment and the subsequent analysis of three portions yielded inconsistent data. Results which could be shown to be statistically significant

were obtained by the performance of ten experiments on ten separate days, taking one portion from each experiment for bacteriological analysis. On the basis of ten experiments for each different series, effects of experimental error were minimized and comparisons could be made on the efficiency of various types of initial mixing.

By statistical methods of analysis it was shown that consistently lower M.P.N. values were obtained in chlorinated sewage which had been initially mixed than in sewage into which the chlorine solution was permitted to flow from the pipette without subsequent mixing. No significant difference was noted between the results obtained with rapid or slow mixing.

By the application of other statistical techniques it was shown that a valid method of chlorination control could be derived. The basis for this method is the performance of four series of experiments on ten separate days, and the evaluation of the results by comparison of chlorine residuals with the per cent of time a stipulated value of M.P.M. of coliform bacteria could be attained. The M.P.N. value chosen for illustration was a coliform index of 300 per 100 ml. It was shown that with thorough initial mixing the M.P.N. values would be 300 or less for 50 per cent of the time when a chlorine residual of 0.55 p.p.m. was maintained after a 10-min. contact period. In contrast to this, when no initial mixing was provided, it was necessary to maintain a chlorine residual of 1.1 p.p.m. in order to achieve the same results.

On the basis of the results of the experimental work reported in this paper, together with the application of statistical techniques to the analysis of the results, it may be concluded that:

1. Ten separate experiments, with one portion withdrawn for analysis from each experiment, are necessary in order to achieve significant results for any particular observation.

2. The results of two different series of ten experiments each may be compared by statistical methods to determine the significance of any differences in the method of treatment employed in each series of experiments.

3. Thorough initial mixing of chlorine solution and sewage prior to the period of contact gave consistently better chlorination efficiency than when no mixing was employed.

4. Actual chlorine dosage maintained at a fixed value in parts per million is not a reliable method of control of the chlorination process in any sewage treatment plant.

5. The rational method of chlorination control is to maintain a fixed value of chlorine residual in the sewage after a specified contact period in order to attain a stipulated coliform index in the effluent 50 per cent of the time.

6. The chlorine residual necessary to achieve the stipulated coliform index may be predicted for any sewage treatment plant by the performance of four series of ten chlorination experiments, and statistical evaluation of the results of these experiments.

Appendix

Statistical Methods

To achieve the desired objectives of this paper, it was necessary to subject the results of many bacteriological and chemical observations to statistical methods of analysis. These statistical operations were performed on the logarithms to the base 10 of the M.P.N. values. The use of $\log_{10}$ rather than recorded values of M.P.N. led to certain advantages in the mathematical treatment of the data, and may be considered valid for the following reasons:

1. The determination of the M.P.N. is based upon a geometric ratio of dilutions of the sewage being sampled.

2. The death rate of bacteria induced by chemical disinfection is generally considered to be a logarithmic function.

3. The series of $\log_{10}$ of M.P.N. values follow the normal probability curve more closely than the values of M.P.N., thus permitting a more accurate evaluation of the data.

The symbol M was used to represent the arithmetic mean of the logarithms of the M.P.N. of coliform bacteria and formed the basis of most statistical operations.

Standard deviation σ_X was used as a measure of the dispersion of the results of each series of experiments. Mathematically σ_X may be expressed as follows:

$$\sigma_X = \sqrt{\frac{\Sigma(X - M)^2}{N}}$$

where X = $\log_{10}$ of the M.P.N. of coliform bacteria per 100 ml. for each observation.

M = arithmetic mean of the logarithms of a series of M.P.N. observations.

N = number of observations in a series.

The value of the standard deviation derived from the above operation is independent of the particular distribution curve which the logarithms of the M.P.N. values may follow.

From the standard deviation obtained for each series of experiments, the standard error σ_M may be derived in accordance with the formula:

$$\sigma_M = \frac{\sigma_X}{\sqrt{N}}$$

where σ_M = standard error.

σ_X = standard deviation of the observations.

N = number of observations or samples.

This term is particularly useful in evaluating the significance of any differences in the results of two series of experiments, particularly when comparing the effects of two types of initial mixing of chlorine and sewage.

The statistical method of determining the significance of differences in two series of experimental results is based upon the difference σ_D in the standard errors σ_M of each of the series and its relationship to the difference D of the arithmetic means M of the values of $\log_{10}$ M.P.N., previously described. This relationship is expressed as follows:

$$\frac{M_1 - M_2}{\sigma_{M_1} - \sigma_{M_2}} = \frac{D}{\sigma_D}$$

By means of the theory of probability it can be proved that if the ratio of D/σ_D has a value greater than 2.5, the chances are 79.5 to 1 that the differences in the results of the two series of experiments are not due to chance variations in the aforementioned factors contributing to experimental errors. Rather, the probabilities are 79.5 to 1 in favor of the differences being attributable to the major environmental factor being studied in the experiments.

Specifically, in the experiments reported in this paper, where ratios of D/σ_D greater than 2.5 were obtained in the statistical analysis of the data, it was assumed that the differences in bacterial kill were beyond any reasonable limits of experimental error. Values greater than 2.5 were assumed to signify that the method of mixing, or other factor being analyzed, was responsible for the difference in results. At least, the laws of probability state that the chances are 79.5 to 1 in favor of the validity of the assumption.

In some instances it was necessary to utilize the chi-square X^2 test in ascertaining whether the difference between two series of observations were of true significance. This test was used to compare a series of theoretical or expected occurrences. Specifically, in this paper the test was used to compare the number of occurrences of the M.P.N. of coliform bacteria at or below

a stipulated index with the theoretical number of times this index could be expected to be reached. Mathematically, the chi-square expression is:

$$X^2 = \frac{\Sigma(T - O)^2}{T}$$

where T = theoretical number of observations in a certain category.

O = the actual number of observations in that category.

The use of this test involved setting up a four-fold table for the evaluation of T and X^2 from the observed bacteriological data.

For the comparisons made in this paper, where the values of X^2 exceeded 5.0, it was assumed that the chances were very great that the differences between the results of two series of experiments were significant. Where the test for a "small" chi-square (χ^2) was applied, a value greater than 6 was considered to indicate a significant difference in the results.

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OXIDATION PONDS *

Report of the Committee on Sewage Disposal, Engineering Section, American Public Health Association

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The use of oxidation ponds to attain secondary treatment of sewage first appeared in California in 1924. Later, in California and Texas, many installations were made, including two at army camps in Texas and one at a naval station in California. One installation is reported in Nevada.

Early History and Development

The sewage treatment value of ponds (1) was accidentally discovered at Santa Rosa, Calif., in 1924, in ponds formed by the clogging of a prepared gravel seepage area. In the same year, septic tank effluent was impounded at Vacaville during the summer. The effluent contained 7 to 15 p.p.m. of dissolved oxygen and 12 to 30 p.p.m. of 5-day B.O.D., some nitrate, and *B. Coli* between 1 and 50 per ml. At Sonoma, 8 acres of ponds were constructed in 1929 to treat septic tank effluent. In a detention period estimated at 20 days, the B.O.D. was reduced to 20 p.p.m. and *B. Coli* to less than 100 per ml. The D.O. varied from 4 to 14 p.p.m. Eventually these ponds were abandoned because of overloading by industrial wastes.

In Texas, Giesecke and Zeller (2) found in 1930 that oxygen was supplied by a lake at the rate of about 75 lb. per acre per day. In a layout to handle settled sewage, an area of 5.25 acres was indicated, assuming 300,000 g.p.d. flow, a B.O.D. of 170 p.p.m. in the settled effluent, an oxygen supply by atmospheric reaeration of 70 lb. per acre of pond per day, and an effluent with a B.O.D. under 25 p.p.m. The pond covered 10 acres as built, however, and within six months was enlarged to 14 acres. The B.O.D. of the settled sewage was actually 375 p.p.m., which increased to 475 p.p.m. due to wastes from cattle slaughtering. The calculated detention period was 108 days at 300,000 gal. per day. Out of a total operating period of 31 months, between May, 1935, to April, 1936, the B.O.D. of the effluent rose from 9 to 10 p.p.m. in the first 4 months, declined to 8 p.p.m. in the following 5 months, and rose to 50 p.p.m. in the next 2 months. Heavy rains tended to reduce the B.O.D. The evaporation from the surface of the pond ranged from 0.1 to 0.22 in. per day. In summer, the rate was higher, but rainfall interfered with operation and prevented accurate calculation. No nuisance occurred from odors. Breeding of mosquitoes was prevented by periodic cutting of weeds and grass, and the introduction of top minnows.

In California, Gillespie (3) found in 1944 at least 25 installations, of which four used ponds only and the others had some form of preliminary treatment, usually sedimentation.

Current practice is illustrated at the U. S. Naval Station, Shoemaker, Calif. (6). Sewage treatment here consists of separate sedimentation and sludge digestion, treatment of clarifier effluent in oxidation ponds (100 acres in area and about 300 acre-ft. in volume), and chlorination of pond effluent when required. The population tributary

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varied from 30,000 to 50,000 during 12 months, or 300 to 500 persons per acre. The sewage flow varied from 4 to 5.7 m.g.d., or 108 to 148 g.p.d. per capita. In the final effluent, the D.O. varied from 0 to 15 p.p.m., the suspended solids from 25 to 100 p.p.m., the B.O.D. from 15 to 50 p.p.m., and the nitrite from 0.0 to 0.4 p.p.m. Primary settling removed 63 per cent of suspended solids and 39 per cent of B.O.D. The oxidation ponds removed 16 per cent of the suspended solids and 46 per cent of the B.O.D. The entire plant removed 79 per cent of the suspended solids and 85 per cent of the B.O.D.

Principles of Design

Caldwell (1) describes the principles of design and the performance and operation of sewage oxidation ponds. He agrees with O'Connell and Gray (4) that sewage oxidation ponds should not be attempted where soil is loose or sandy. Caldwell advises that the sewage be clarified, but not septicized. For ponds receiving settled domestic sewage, the minimum detention time should be 25 days, with a minimum surface area of 1 acre per 400 contributory population. Three feet is regarded as a minimum depth.

O'Connell and Gray (4) suggest working depths of 4 ft. and at least 20 days detention. Burden (5) recommends not less than 4 ft. and not over 10 ft. depth, with detention periods ranging from 5 to 20 days. The above loading figure corresponds to an average clarified sewage B.O.D. loading of 45 lb. per acre per day, or approximately 15 lb. per acre-ft. per day. In the military installations (6) the design capacities varied from 400 to 700 persons per acre, or 25 to 50 lb. B.O.D. per acre-ft., with detention periods from 20 to 30 days.

In Texas, the current B.O.D. loading varies from 20 to 40 lb. of B.O.D. per acre-ft. per day (5). The reduction of B.O.D. is about 50 per cent. The D.O. frequently reaches 25 p.p.m. during the day. Coliform bacteria may be reduced from 100,000 to 50 per ml. Loadings used in Texas appear much higher than those used in California, but are less than those found at military establishments.

Caldwell suggests (1) that ponds be divided into two or more individual units. The incoming clarified sewage should be thoroughly mixed with the contents of the pond, distributing the sewage over the entire pond area, if possible. In large ponds, recirculation of effluents has been proposed. Where the units vary in size, the sewage should be distributed to the units in proportion to their respective areas. A freeboard of at least 2 ft. is recommended.

Operation

Control of Odors

To control odors, Caldwell (1) recommends rapid and thorough mixing of the incoming clarified sewage with the partially oxidized pond water. In abnormal conditions, the use of sodium nitrate may be beneficial, in amount to satisfy 20 per cent of the 5-day B.O.D.

In Texas, Burden (5) warns that "the odor trouble is usually caused by overloading the ponds." Classen (7) believes that "if ponding is used as a method of complete treatment, the pond or lake should be located not less than five miles from the town or other concentrations of population, and should be of such capacity as to provide a detention period of at least six months."

Cleaning Ponds

According to Caldwell (1), ponds may require cleaning every 6 or 8 years.

Control of Weeds on Banks

Earth banks should be kept free of weeds by cutting or by the use of soil sterilants such as sodium arsenite (2 lb. per 100 sq. ft.) once in 3 or 4 years.

The weeds should be cut before applying the chemical (1).

Control of Aquatic Weeds

Aquatic weeds seldom occur in ponds over 2 ft. deep. Tule and cattails, once started, may grow in water 3 ft. deep. To eradicate such weeds, the pond should be drained and the growth cut off close to the ground. The pond is then filled to a depth of about 1 foot. "Benoclor" may then be sprayed over the pond (15 to 20 gal. per acre). After several days the pond is ready for service. Such treatment may serve from 1 to 3 years (5). In Texas a minimum depth of 4 ft. is used to avoid tule and other growths.

Mosquitoes

Mosquitoes can be eliminated (1) by removal of weeds from the shore line and by maintenance of the slope on banks. Mosquitoes may be controlled (4) by fish (*Gambusia affinis*), or by the application of a light oil spray once a week in hot weather or once every 3 weeks in cool weather. At Shoemaker, Calif. (6), no mosquito nuisance developed.

Operating Phenomena

Various observers report an increase in algae during the summer, with intense activity during daylight hours, attended by a reduction of CO_2 and bicarbonate ion concentration (6). The dissolved oxygen reaches a high degree of supersaturation in the ponds. The effluent D.O. ranges from 0 to 25 p.p.m. In the primary effluent at Shoemaker, Calif., the ammonia nitrogen averaged 20 to 30 p.p.m. In the final effluent, during the summer, low values were found; in September, 1944, less than 1 p.p.m.

Status of Sewage Oxidation Ponds

In 1942, Gillespie appraised (1) the status of sewage oxidation ponds, explaining the lack of favor "by their crudity compared to neat engineering structures, the unattractive green coloration of the effluent, and perhaps the fact that too few engineers are aware of their potentialities for oxidation of organic matter. Properly laid out for size and embodying a few simple details, oxidation ponds absorb and destroy the odors of sewage, leaving nothing worse than the smell of a swamp. The effluents are permanently stable, with B.O.D. values as good or better than those of trickling filter effluents. As a destroyer of sewage bacteria, they possess almost unbelievable efficacy. Final overflow from ponds designed for 15 days detention will show 5 to 50 *B. Coli* per ml., compared to something like 100,000 per ml. in the original sewage. Such results continue day after day, and therefore will rank with or outrank the results from chlorination in reliability."

Limitations

The phenomena of the oxidizing action occurring in sewage ponds appear more definitely related to photosynthesis and algal activities than is the case with other oxidizing devices for treating organic matter. In sewage ponds, the content of dissolved oxygen is at a minimum during the pre-dawn hours or cloudy weather. The ponds must therefore be conservatively designed so that the excess of dissolved oxygen produced during sunlight will carry through the night hours, and through periods of cloudy weather. Such sewage ponds are most adaptable to the Southwest where favoring conditions are light rainfall, much sunlight, and relatively high air temperatures. In northern areas, where the air temperature for several months of the year may fall below 32° F., sewage ponds do not appear suitable, unless for emergency use in the warmer months.

Economy

Apparently where climatic conditions are favorable and land is cheap,

sewage ponds may afford economical treatment. Thus they may have value for the small communities where the cost of sewage treatment must be kept to a minimum.

Industrial Applications

Ponding of industrial wastes, often referred to as "lagooning," has been practiced for many years. The method has been applicable particularly where the industrial operations are seasonal.

It is to be noted, however, that ponding of industrial wastes may be resorted to for other purposes than as a means of achieving oxidation, such as (a) for sedimentation to remove solids, (b) for storage and controlled discharge according to available dilution in receiving streams, and (c) for digestion, storage and drying of solids.

Beet Sugar Wastes

In the beet sugar industry, Eldridge (8) notes that flume water has been settled in ponds made by building dikes around an area varying from a few acres to as much as 50 acres. He suggests that sludge ponds for solids from flume water and from coagulation and sedimentation of process water be large enough to hold the entire volume of sludge from a campaign. Such ponds should be well diked, without overflow. For a factory handling 1,000 tons of beets daily for 100 days, he suggests a volume of 293,000 cu. ft. or 1.1 acres 6 ft. deep. Lime slurry has also been ponded, usually in a separate pond. The supernatant is highly polluted and may cause trouble, unless discharged at time of high river flow.

Settling ponds were in use (9) in 1919 at Caro, Mich. (3.6-day period) and at Decatur, Ind. (1.7-day period) on beet sugar wastes. The latter plant has since been abandoned.

Dittoe (9) noted that in 1910 at Paulding, Ohio in a sugar factory handling 900 tons of beets daily (2.5 to 3.0 m.g.d. waste), there were separate settling ponds for three types of wastes. These proved insufficient. In 1916, for the treatment of 3 m.g.d. of wastes, 5/64-in. screens and chemical treatment were provided before discharge to settling ponds having a total volume of 5.6 million gallons.

At Mason City, Iowa (10), the diffusion battery or pulp waste from a beet sugar plant is treated in eight ponds occupying 40 acres. Of these, five have an area of 22.5 acres. The waste is pumped into one pond, and flows in turn through the others. The Steffens waste is pumped into two large ponds for winter storage and is discharged into the river at high water.

McDill (10) believes ponding has a definite application in the beet sugar industry, but that its success depends on waste elimination or modification or re-use. He does not favor ponding of total waste volumes.

Cannery Wastes

The wastes from canning of fruits and vegetables aggregate a large volume of solid and liquid waste (11). As a rule, the re-use of water within a cannery is impractical. The solid wastes should theoretically yield a large quantity of usable by-products. However, such procedure is handicapped by the seasonal nature of the business, the perishable nature of the waste, and the reluctance of canners to add additional equipment.

In 1940, Sanborn (12) conducted field tests on the use of sodium nitrate in ponds holding cannery wastes. The nitrate furnishes oxygen to the bacteria decomposing the waste organic matter, after the dissolved oxygen in the liquor is exhausted.

Many corn canneries now screen the corn waste liquor and pump it to lagoons, or ponds, after adding 150 lb. commercial sodium nitrate (16 per cent N) to the waste from 1,000 cases of No. 2 cans.

Ryan (13) experimented in 1944 on pea waste at Red Creek, N. Y. All

process water, waste, and wash water (some 20 gal. per case of No. 2 cans), plus ensilage juice from the pea vine stacks, was pumped to the lagoons. About 10 tons of sodium nitrate were added during July to a lagoon holding 5 million gallons. The 5-day B.O.D. of the lagoon liquor rose from 750 p.p.m. on July 31 to 1,400 p.p.m. on August 10, and declined to 57 p.p.m. on October 27, and to 0 on December 12. At the start the lagoon contained considerable rain water.

According to Warrick (14), a lagoon should hold the wastes from the pack of an entire season. A shallow lagoon (depth under 4 ft.) with a large area is preferable. Where nitrate is applied, there is no need for an absorptive soil.

Cooperative work by the health departments of Illinois, Indiana, Iowa, Minnesota, Missouri, and Wisconsin, with the National Canners Association and the Wisconsin Canners Association, produced a bulletin on "Cannery Waste Disposal Lagoons" (15). Lagoons are broadly classified as absorption lagoons or as storage lagoons. The conclusions are that regardless of the method of disposal, efficient screening through a 40-mesh screen is required. Cooling tank waters should be discharged separately. Silage or stack juices should not be discharged to a lagoon. Lagoon treatment offers possibilities in complete treatment as a relatively low cost but requires considerable area. The choice among several types of lagoons will depend largely upon the nature of the soil and the proximity to inhabited places. Sodium nitrate-treatment offers the advantage of positive odor control. According to Warrick (14), ammonium nitrate has also been used.

Storage lagoons (15), when sodium nitrate-treated, can be used for pea, corn, beet, lima bean, and green-bean wastes. If untreated, they should be located a considerable distance from habitations. Sometimes a half mile has not been sufficient to avoid complaints. Surface treatment with oil has been unsuccessful in suppressing odors.

Absorption lagoons may be irrigation fields (where the soil is porous and affords rapid absorption) or lime or sodium hydroxide-treated absorption lagoons (requiring porous soil). These require a considerable distance from habitation because of odors.

Citrus Canning Waste

In Florida, Ingols (17) discusses two distinct citrus canning wastes; one, the wash waters from the plant itself; the other, a press liquor containing 8 to 10 per cent solids. He indicates that occasionally the canning wastes have been lagooned, as well as the press liquor. The latter is likely to be odorous. However, McNary (18) states that press liquor cannot be lagooned satisfactorily, because it contains too much unstable organic matter. Nevertheless, a certain amount of lagooning is practiced, principally as an emergency measure.

Chemical Wastes

At the Dow Chemical Company plant at Midland, Mich. (19), about "one million gallons daily of waste brines result from bromine, calcium chloride, Epsom salt, and magnesium manufacturing processes. This brine, about eight times as strong as sea water, is stored in some 400 acres of ponds and released during periods of high stream flow." The pond dikes are made of clay. During the discharge period, the salt content of the river immediately below is kept up under 5,000 p.p.m. as sodium chloride.

Distillery Wastes

Zack (20) describes the situation at a distillery where 60,000 gal. per day of "slop" were wasted to large pits as a temporary measure. This proved unsatisfactory and was replaced by a plant to produce cattle feed from the wastes.

Strawboard Wastes

Part of the wastes from strawboard mills (8) consists of cooking liquors and the wash waters from the beaters and washing machines. These are usually high in organic solubles and suspended solids. Such liquors are frequently ponded in large diked areas, and discharged to a stream at time of high water. The odors from such ponds may create a nuisance over a considerable area.

Tannery

Eldridge suggests (8) that beam house wastes from a tannery may be ponded, and the sludge therefrom discharged to a series of large storage lagoons. The lime wastes should be lagooned.

Metal Plating Wastes

Certain wastes resulting from electroplating of metals carry significant amounts of cyanide. Such wastes should not be discharged into a stream unless the volume of stream flow can at all times reduce the cyanide concentration below the fatal dose for aquatic life, which is about one part in two or three million. Such waste waters containing cyanide are frequently ponded (8). The ponds are usually enclosed by a strong fence and posted with warning signs. The time required for the complete decomposition of cyanides in ponded wastes is not definitely known.

Wastes from Oil Fields and Refineries

In the separation of oil from brine in flotation tanks, an auxiliary tank or pond is often provided for protection against loss due to spills and breaks (8). In some sections, brine is disposed of by evaporation and seepage in large ponds. As the ponds eventually become full, the excess brine is discharged during high water into the nearest watercourse.

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SEWAGE WORKS SHORT COURSE TRAINING

The Engineering Section Project of the American Public Health Association recently released a progress report on its study of Sewage Works Short Course Training. This study is a part of the Engineering Section Project's endeavor to correlate and coordinate information relating to the training and utilization of sanitary engineers in environmental control.

The Project's questionnaire concerning sewage works short course training in 1947 was sent to all state health departments. As of September 20, 1948, 38 replies had been received.

Twelve states reported sewage works short courses in operation, with twenty-six states indicating a lack of such programs. The number of such courses given in 1947 was forty-one. The agencies by which they were sponsored are:

State Health Departments—15 courses
Local Health Departments—0 courses
Public Official Agency—3 courses
Professional Sewage Works Organizations—12 courses
Colleges and Universities—11 courses
Local Sewage Works Departments—0 courses

Considerably more than 2276 persons received short course training during 1947, this being the number reported by 10 of the 12 states returning the questionnaire. Two of the states had no record of the number trained during that year.

Short courses were given at 10 universities and at 7 other locations. Duration of these courses ranged from 1 to 15 days, 3 being as short as 1 day and one as long as 15 days. Three courses were for 2 days, three for 3 days, one for 4 days, three for 5 days, and the duration of two courses was not reported. Nearly all of the training courses were set up for annual sessions, 13 of 16 being on this basis. One school is held semi annually and one bi annually.

Four states held more than one type of school, with two of these having two types each. The most popular geographical basis for holding short courses appeared to be that of the statewide group, 12 being of this type and 5 on a regional basis. No courses were reported for purely local groups.

The following types of persons attended the various short courses:

Operators—15 schools
Superintendents—12 schools
Managers—5 schools
Public Health Agency men—4 schools
Miscellaneous—9 schools
Unknown—1 school

Registration costs varied considerably, ranging from no cost to $50.00. Six courses had no registration charge. For one the charge was $1.00. Two courses had a $2.00 charge, one a $7.50 fee, one a $50.00 fee, and for five schools the registration cost was not reported.

In this study, where a series of regional schools was held it was counted as one course. For example, Oregon reported several regional sessions, Oklahoma five, and Texas thirty-two district sessions. Each of these series was counted as only one course in the report.

Further information concerning this survey may be obtained from the Engineering Section Project, American Public Health Association, 1790 Broadway, New York 19, N. Y.

SIMILARITIES AND DIFFERENCES BETWEEN A BIOFILTER AND A STANDARD FILTER*

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In sewage treatment processes the practical applications have generally preceded the proper understanding of the mechanisms responsible for purification. This is especially true with complex biological treatment processes such as activated sludge, sludge digestion, and trickling filters. Even after years of successful and widespread applications of these processes, there is still no complete and rational explanation of the sequence of events leading up to purification and stabilization. Theory can be overlooked when these processes work successfully, but when the process is upset and fails to produce the expected results, the theory is put to a strain and many contradictory opinions are expressed. Consequently, the remedies suggested are likewise contradictory, and may not always prove effective.

The successful development of high rate filtration is an example of a situation where empirical practice has outstripped fundamental knowledge and research.

High rate filtration practice has, on the whole, justified the claims of those responsible for the development of the several processes. The performance of the high rate filter as well as the standard filter with varying quantities of applied load and under various environmental conditions has been carefully studied. The effectiveness of such filters, however, is the result of biological activity of the film, and therefore, information regarding the quantity and quality of the film is of utmost importance. Such information is lacking for high rate filters. In standard filters the accumulation and discharge cycles of the film, and the changes in the biological population have been studied. The biochemical characteristics of the film of the standard filter have not been investigated.

Scope of Study

A study of the chemical composition, biological population and biochemical activities of the film should reveal whether the fundamental difference between a high rate filter and conventional filter is quantitative or qualitative; whether the purification is brought about by similar mechanisms in the two types of filters—different only in the rate of reaction—or by entirely different mechanisms. Is biochemical oxidation of importance in a high rate filter or is the purification due primarily to "colloider" action—a continuous removal of the impurities from sewage by adsorption and immediate and continuous discharge of the agglomerated solids? If the solids removed from sewage are retained in the bed for some time, what is the extent of biochemical stabilization?

It has been assumed in this study that the differences in the chemical characteristics in the film in a given bed at different levels and at different seasons are the result of biochemical activities. An increase in the stability of the film with increasing depth and during the warmer weather, as measured by the different criteria, has been attributed to the action of microorganisms living within the film. Just as in sludge digestion, where certain well-defined and measurable differences exist between

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the raw and the digested sludge, there should be differences in chemical characteristics between the surface film and that at different levels. If biological action is of importance, there also should be an increased rate of stabilization and decomposition of the film during the summer.

The criteria used for determining the extent and rate of biochemical decomposition of the film were: (1) ash content, (2) B.O.D., (3) grease, and (4) total nitrogen.

High rate filters do not produce appreciable quantities of nitrates. This might constitute a bona fide difference in the biochemical characteristic of the film from that of the standard filter. Before such a conclusion can be accepted, however, it must be proved that a nitrifying flora is not established in the high rate filter. It is at present not known whether the absence of nitrates in the effluent from high rate filters is due to the failure of establishment of a nitrifying flora or to inadequate contact time.

Evidence regarding the types and numbers of the protozoan populations of the films might also be useful in establishing similarities and differences between the two types of filters. This information was obtained by Dr. J. Lackey of the Sanitary Engineering Division of the United States Public Health Service at Cincinnati. Only enough of the extensive data available will be presented here to establish whether there are essential differences in the biological population between the two types of filters.

In short, this paper will present, from the extensive results obtained during a year's study of the biofilter and the standard filter, such portions as may throw light on the questions raised above. A more detailed presentation of the material dealing with this and other phases of the study has been given in a series of papers previously published (1).

The theme of this paper may be formulated as follows: (1) Is the biofilter fundamentally different from the standard filter in respect to chemical and biological composition of the film? (2) If there are differences, do they pertain to rates or types of reactions?

Description of Study Plants

The high rate filter studied was of the biofilter type located at an army embarkation camp and put in operation in October, 1942. The treatment consists of single stage complete treatment, with recirculation from the filter effluent to the primary clarifier and also from the final effluent to the filters. The plant was designed for a flow of 3.5 m.g.d., with two primary and two secondary clarifiers and two filters. The filters are 3 ft. deep. The sewage is fresh and strong (ave. B.O.D. 212 p.p.m.). The flow varies considerably according to the contributing population. Design loading of the filters was 1.5 lb. B.O.D. per cubic yard per day. The actual average loading during the period under study was 1.4 lb. of B.O.D. per cubic yard of stone per day, or 2,250 lb. per acre-ft. per day.

The standard filter is a part of the Manville, N. J., sewage treatment plant, which treats domestic sewage and has been in operation since 1938. The filter is 6½ ft. deep and is furnished with a two-arm rotary distributor. The rate of application of sewage on the filter is 3.8 m.g.a.d., but the sewage is weak (ave. 170 p.p.m. suspended solids during the 8-hr. day) as a result of considerable infiltration. The estimated application of B.O.D. is 500 to 600 lb. per acre-ft. per day.

Methods

Stone samples from the top, 1-ft., and 2-ft. levels were taken once or twice a month during an entire year. A total of 22 sets of samples were col-

lected from the biofilter and 17 from the standard filter. A sample of the film from the 6-ft. level of the standard filter was taken by flooding the bottom foot of the bed and catching the flushing at the entrance of the secondary clarifier. The stone samples from each level, amounting to 20 to 25 lb., were scraped into water. The weight of the stone, the volume of the sludge obtained, and the quantity of the film per kilogram of stone were calculated from the amount of dry solids in the collected material.

The chemical and biochemical characteristics of the film were measured by the ash, B.O.D., grease, and nitrogen contents.

The nitrification capacity of the film was determined by aerating a sample of the film containing the equivalent of 1 gm. of solids with a liter of sewage for 24 hours, at which time the quantity of nitrites and nitrates in the supernatant liquor was measured. The presence of nitrites or nitrates was taken to signify the presence of nitrifying organisms in the film in numbers greater than those present in sewage, since the latter by itself does not nitrify after 24 hours of aeration. It is not claimed, however, that there is a quantitative relationship between the amount of nitrites and nitrates produced under these conditions and the number of nitrifying organisms.

Results

The ash, B.O.D., grease, and nitrogen values at the three levels are averaged for the entire period of study and presented in Figure 1. The average ash content of the film in the biofilter was about 26 per cent and in the standard filter 33 per cent. The B.O.D. of the film was 500 and 400 gm. per kg. of solids, respectively, in the two filters. The grease on the basis of solids was 10 per cent in the biofilter and 7.5 per cent in the standard filter. The nitrogen on the basis of solids was 8 per cent in the former and 7 per cent in the latter.

The average values for the three levels show a greater degree of stabilization of the film in the standard filter than in the biofilter. They do not show, however, the changes in the composition of the material in each filter with increased depth.

In Figure 2, the average yearly values at the top, 1-ft., and 2-ft. levels are presented. It will be seen that there is a progressive vertical increase in the ash content of the film, but that the increase in the standard filter is greater than in the biofilter at respective depths. The B.O.D. of the solids at the top and 1-ft. level of the biofilter is practically the same, and decreases slightly at the 2-ft. level. The B.O.D. in the standard filter decreases

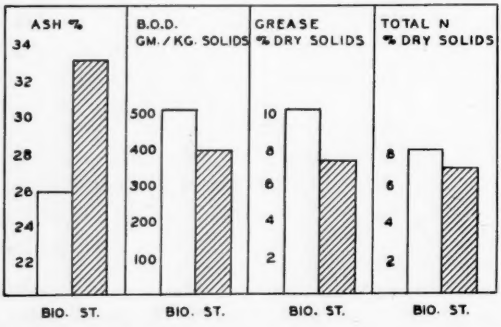

FIGURE 1.—Average ash, B.O.D., grease and total nitrogen contents of the film at the top 2-ft. level of the biofilter and standard filter.

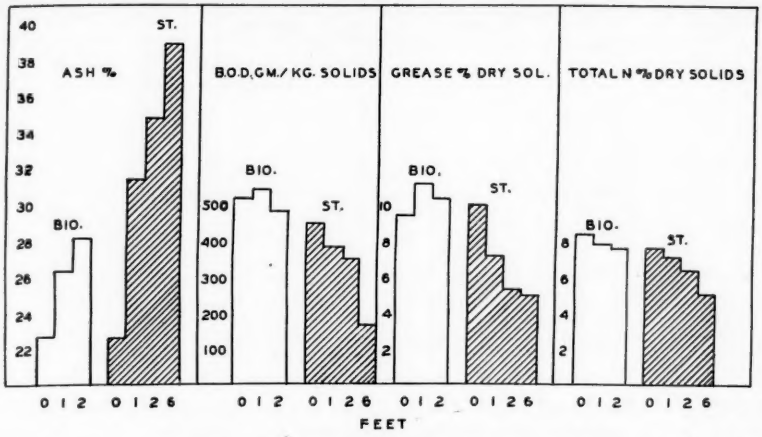

FIGURE 2.—The average ash, B.O.D., grease and total nitrogen contents of the film at the different levels of the biofilter and standard filter.

with depth and is lower than in the biofilter at equivalent depths. The grease content in the biofilter increases somewhat with depth, but in the standard filter undergoes material reduction. The nitrogen in the biofilter does not change materially with depth, but in the standard filter it decreases appreciably.

The higher percentage of grease in lower levels than at the top of the biofilter might be explained on the basis of greater adsorption of this material at lower levels in comparison with the top. It might be expected that the short contact time available, due to higher flow velocities at the top, does not permit an appreciable removal of grease at the top. As the velocities are reduced below the surface, a greater opportunity for the removal of grease is afforded. If this explanation is true, then a lower grease content with increasing depth in the standard filter can be due to the same phenomenon in reverse, namely, to the relatively greater adsorption of grease in the top in comparison with the lower levels. The flow velocities in the surface of the standard filter are sufficiently low to allow a relatively greater adsorption at the top. But as is shown below, the differences in the grease content with increasing depth during the summer and winter cannot be attributed to any other factor than to biological decomposition. Furthermore, the differential adsorption due to change in velocity of flow of sewage in the bed could hardly be assumed to apply to the ash content of the film.

The percentage increase of ash over the top level with increasing depth during the summer and winter is compared in Figure 3. The increase in ash is less in the biofilter than in the standard filter both in summer and in winter. However, the ash increase in the biofilter is greater in the summer than in winter. The increase amounts to 30 per cent in the summer and 10 per cent in the winter. In the standard filter the ash increased by 65 per cent at the 2-ft. level in the summer with only a small increase in the remaining 4 feet. In the winter the full 6-ft. depth was required to produce results equivalent to the 2-ft. level in the summer.

In Figure 4, the percentage increase or decrease of B.O.D. over the top level with increasing depth during the summer and winter is compared. During the summer period the B.O.D. in

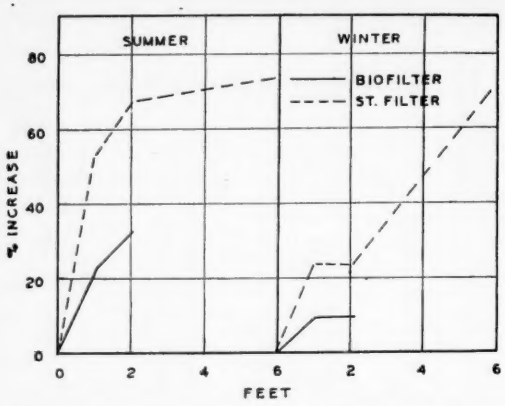

FIGURE 3.—Percentage increase in the ash of the film with depth in biofilter and standard filter during summer and winter periods.

both filters decreased. The rate of decrease is greater in the standard filter. At the 2-ft. level the decrease in the biofilter was 20 per cent and in the standard filter 26 per cent. In the winter the B.O.D. in the film of the biofilter manifested an increase over the top level, while in the standard filter there was a decrease, although at a lower rate than in the summer.

The percentage increase or decrease of grease on the basis of dry solids in the film at the different levels of the beds is presented in Figure 5. The decrease in the biofilter was low during the summer, amounting to 10 per cent at the 2-ft. level, while in the standard filter at the same depth the decrease was 36 per cent and at the 6-ft. level 45 per cent. There was an actual increase in the percentage of grease at the 1- and 2-ft. levels of the biofilter in the winter in relation to the top level. In the standard filter the percentage decrease appears to be higher in the winter than in the summer. This is due to the fact that the grease content of the film at the top of this

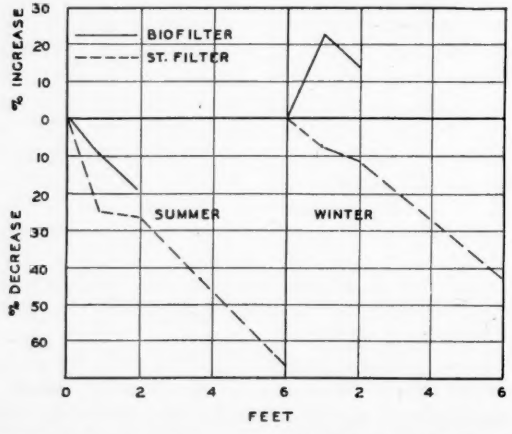

FIGURE 4.—Percentage decrease or increase of the B.O.D. of the film with depth in the biofilter and standard filter during summer and winter periods.

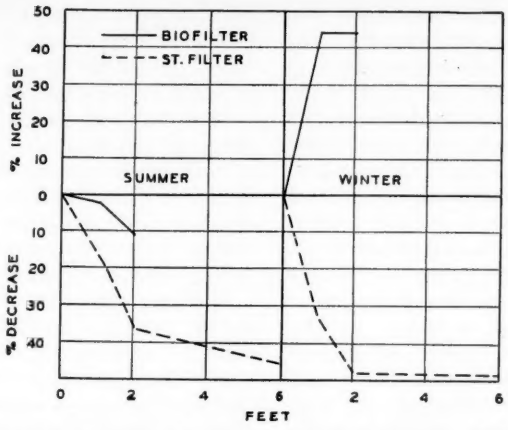

FIGURE 5.—Percentage decrease or increase of the grease content of the film with depth in the biofilter and standard filter during summer and winter periods.

filter in summer was 6.7 per cent and in the winter 13.2 per cent; hence, the percentage decrease was lower in the summer period.

The percentage decrease in the total nitrogen content of the film in the filters is given in Figure 6. The decrease in the summer was 13 per cent in the biofilter and 21 per cent in the standard filter at the 2-ft. level. In winter the percentage of decrease in both filters was lower.

The results pertaining to the nitrification capacity of the filters are given in Table I. On occasions, small amounts of nitrites and nitrates were present in the effluent from the biofilter plant. The nitrites in the effluent averaged for the entire period 0.3 p.p.m., and the nitrates 0.7 p.p.m. The maximum quantity of nitrites and nitrates produced did not exceed 4 p.p.m., and these occurred during the summer. The nitrates in the standard filter averaged 8.4 p.p.m. for the entire period and frequently were 10 p.p.m. or higher.

TABLE I.—Nitrifying Capacity of the Biofilter and the Standard Filter

Level	Nitrites and Nitrates Produced (p.p.m.)	
	Biofilter	Standard Filter
Top	8.5	6.1
1-ft.	5.7	7.4
2-ft.	6.3	9.3
6-ft.	—	2.0

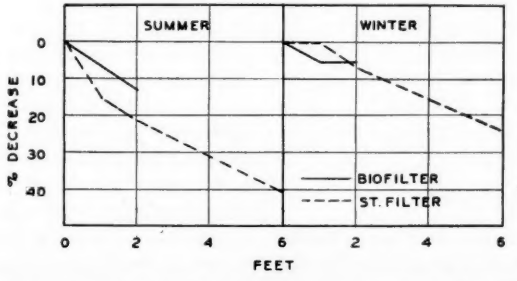

FIGURE 6.—Percentage decrease of the total nitrogen content of the film with depth in the biofilter and standard filter during summer and winter periods.

The nitrifying capacity of the film in the biofilter as determined by the method described above was high. It was somewhat higher in the film obtained from the top of the biofilter than at the lower levels. In comparison with the standard filter it was higher at the top level and lower in the next two levels. It is of interest to note that the maximum nitrification capacity in the standard filter was at the 2-ft. level, and that it decreased sharply at the 6-ft. level.

The average numbers of ciliates, flagellates, and Rhizopods in the two filters are given in Table II. They are expressed as millions per gram of dry solids, and are the averages of the counts for the entire period at the three levels.

TABLE II.—Average Protozoan Population at the 2-Ft. Level, Expressed as Millions per Gram Dry Film

Type	Biofilter	Standard Filter
Ciliates	1.8	1.9
Flagellates	27.0	18.5
Rhizopods	15.5	16.3

It can be seen that the numbers in the two filters are not materially different, except for flagellates, which are higher in the biofilter. Furthermore, the types of organisms occurring most abundantly were also the same in both filters. For example, of the ciliates, *Vorticellae* was the most common and abundant representative in both filters. Also the colorless flagellates were the most abundant organisms in both filters. Two Rhizopods, namely, *Diplophrys archeri* and *Hartmanella hyalina*, occurred most frequently and in greatest numbers in both filters.

Discussion

The evidence presented above seems to support the view that essentially the nature of the film in the standard filter and in the biofilter is the same. Furthermore, it has been shown that biochemical reactions of the film from both types of filters are extensive and of far-reaching importance.

Both types of filters have an abundant and similar protozoan population. A nitrifying flora is well established in the biofilter, and even in this respect there is little difference between the two filters. The essential difference is quantitative rather than qualitative.

Higher rates of application of B.O.D. and suspended solids do not change the nature and mechanism of purification, but only the rate of reaction. The rate of biological stabilization of the film in the biofilter is lower than in the standard filter. This is evidenced by the lower increase in ash, and by the lower decrease in B.O.D., grease, and nitrogen content of the film from the top down to the 2-ft. level, in comparison with the standard filter at similar depths.

The biochemical nature of the changes in the two filters is further attested by the higher rates of decomposition in the summer period in comparison with the winter. A truly remarkable magnitude of the decomposition is shown by an increase of nearly 70 per cent in the ash content of the film of the standard filter during the summer at the 2-ft. level. Even the 30 per cent increase in ash in the biofilter can be regarded as striking, considering the higher rates of application. The same applies to decomposition as evidenced by the other criteria used, such as B.O.D., grease, and nitrogen content of the film, to a somewhat lesser extent.

There are certain limitations to the evidence which are the inherent result of the method of study and of the assumptions made. The increases in the grease and B.O.D. contents of the film at the lower levels of the biofilter during the winter need a few words of explanation. That the B.O.D. of a material undergoing biological decomposition can increase, especially under anaerobic conditions, is already known.

Whether the increase in the biofilter is due to the higher oxygen demand of the products of decomposition or to a differential adsorption of materials with a higher B.O.D. at the lower levels is difficult to determine. The fact that during the summer there was no increase in the B.O.D. makes the latter explanation less plausible, unless the higher rate of decomposition induced by higher temperatures counterbalances the differential adsorption.

The higher grease content of the film at the lower levels of the biofilter in comparison with the top, in the winter, could be attributed to a differential adsorption due to the high velocities of flow prevailing at the top of the filter. There is also evidence that the film at the top of the bed is not identical with the materials in the sewage coming in contact with it, and that the decomposition processes have proceeded to an appreciable extent even at the top, especially during the summer. The error created by this factor, however, tends to make the estimated rate of decomposition lower than the actual rate, which is, therefore, on the conservative side.

Finally, the evidence on the establishment of a nitrifying flora in the biofilter as obtained by the special method used in this study is so unexpected that it might need a few words of explanation. The question might be raised as to the validity of the interpretation: Is the production of nitrites and nitrates from a biological material under the empirical conditions of the test an indication of the presence of a nitrifying flora? Sewage, which contains relatively fewer nitrifying organisms, produces nitrites and nitrates upon aeration only after 10 to 12 days. It can therefore be accepted that when nitrites and nitrates are produced within 24 hours, the number of nitrifying organisms are greater than those in sewage.

There may not be a direct relationship between the quantity of nitrites and nitrates produced and the initial number of nitrifying organisms, but it cannot be ignored entirely that the biofilter film produced quantities of nitrates and nitrites nearly equal to the film from the standard filter.

That large numbers of nitrifying organisms can exist in the filter, with only limited activity in respect to nitrite and nitrate production, is not difficult to accept. Large numbers of other types of organisms can exist in nature under conditions unfavorable to their activity.

Failure of the nitrifying organisms in the biofilter to produce larger quantities of nitrites and nitrates can be due to the short period of contact and the short period of storage of the film. Nitrification is a relatively slow reaction. With high rates of application and the short periods of storage of the film, adequate time for this reaction may not be obtained. It seems probable that as soon as the rate of application is reduced, nitrites and nitrates will appear in the effluent without an intervening maturing period. The lower the rate of application the greater the nitrates until the rates of application approach those in the standard filter.

Summary and Conclusions

The evidence obtained from a year's study of the chemical, biochemical, and biological characteristics of film at the different levels of the biofilter and the standard filter supports the view that the differences between the two filters are only quantitative, and pertain to rates rather than qualitative differences in the mechanism of purification. Both types of filters remove the materials from sewage by adsorption and "colloider" action.

In both types of filters biological oxidation of the materials removed is of vital importance. The difference between the filters is in the relative magnitude of oxidation in each. As

the load increases, the relative role played by adsorption as against oxidation increases. However, with an average loading of 1.4 lb. B.O.D. per cubic yard per day on the biofilter studied, biochemical oxidation plays an important part, as evidenced by an increase in ash, and a decrease in B.O.D., grease, and nitrogen with increasing depth and with higher temperatures during the summer.

The biofilter has an established nitrifying flora, although the filter may not produce an appreciable quantity of nitrites and nitrates. The protozoan fauna of the biofilter and that of the standard filter are similar, both quantitatively and qualitatively.

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NEW CORROSION PUBLICATIONS AVAILABLE

Two new publications on corrosion are now available through the National Association of Corrosion Engineers, 905 Southern Standard Building, Houston 2, Texas. The publications are:

BIBLIOGRAPHIC SURVEY OF CORROSION—1945. By Robert D. Misch, James T. Waber, and Hugh J. McDonald, all of The Corrosion Research Laboratory, Illinois Institute of Technology, Chicago, Illinois. Published by the National Association of Corrosion Engineers. The book contains 129 pages, $8\frac{1}{2} \times 11$ inches, with cloth binding. The cost is $4.00 per copy to members of NACE, $5.00 per copy to others.

This book contains approximately 1100 references to published articles relating to corrosion, and 170 references to patents, that appeared from January, 1945, to February, 1946, inclusive, in the following publications:

Chemical Abstracts
Corrosion
Corrosion and Material Protection
Engineering Index
Industrial Arts Index
Metals Review

The abstracts are divided into two classes, general material and patents. Each class is divided into nine main groups as follows: (1) types of attack; (2) investigations in corrosion; (3) effects of specific media; (4) effects in specific equipment; (5) resistance of materials; (6) methods of prevention; (7) coatings; (8) removal of corrosion products; and (9) general and miscellaneous considerations.

DIRECTORY OF THE AMERICAN COORDINATING COMMITTEE ON CORROSION, Fourth Issue, published in October, 1947, is now available from the National Association of Corrosion Engineers. This Directory, which occupies 62 6×9-in. printed pages in heavy paper binding, lists the names, addresses, and fields of special endeavor of many of the principal corrosion workers in the United States and Canada. There is a cross-index system so arranged that the name and address of a specialist in some particular phase of corrosion, may readily be found.

The Directory consists of four parts: Section I, a subject index; Section II, an alphabetical index of individuals, including addresses; Section III, an alphabetical index of organizations and companies; and Section IV, a numerical serial number listing of individuals.

Section I is an alphabetical listing of corrosion subjects, under each of which are given the reference number of authors (listed in Section IV) who have contributed to each of the subjects listed. Also, each corrosion subject is given a marginal reference number that is used to indicate the corrosion subject on which each individual (listed in Section II) has contributed. The cost of the Directory is $2.00 per copy.

THE POLAROGRAPHIC DETERMINATION OF DISSOLVED OXYGEN IN WATER AND SEWAGE

By Edward W. Moore, J. Carrell Morris, and Daniel A. Okun

Associate Professor, Assistant Professor, and Teaching Fellow, Respectively, Harvard Graduate School of Engineering, Cambridge, Mass.

The practical importance of the dissolved oxygen determination in the fields of water purification, sewage treatment, and stream pollution is attested by the number of able workers that have devoted their efforts to its improvement. The results of their research are apparent in the space devoted in "Standard Methods" to refinements of the Winkler method. However, it has been recognized by several workers, notably Petering and Daniels (1), Baumberger (2), and Ingols (3), that the polarographic method offers certain possible advantages over the Winkler method. Among these advantages are the rapidity with which a determination may be made, the possibility of determining the dissolved oxygen *in situ*, the feasibility of continuous recorded observations and/or automatic operating control, and the possible use of the sample for other determinations after its D.O. has been evaluated. These potential advantages should be attractive both to researchers and to those doing practical control tests.

Theory of the Polarographic Method

The polarographic method of analysis is based on the measurement of currents produced by reduction of the substance in question at some continually renewed electrode surface. For detailed discussion of the method the reader is referred to the book *Polarography*, by Kolthoff and Lingane (Interscience Publishers, N. Y.; 1941). In practice, the dropping mercury electrode, consisting of droplets of mercury formed at a capillary, is the one usually used, but other electrodes, such as a rapidly rotating platinum electrode, are possible. Each substance has a definite potential at which the reduction takes place, and the maximum current flow associated with the reduction is a measure of the concentration of the substance present. The basic equation derived by Ilkovic for reduction of a substance at a dropping mercury electrode is:

$$i = 605\ n\ D^{1/2}\ m^{2/3}\ t^{1/6}\ C \qquad (1)$$

where

C = concentration of substance
i = average current in microamperes during the life of the mercury drop
n = faradays of electricity required per mole of substance reduced
D = diffusion coefficient of the reducible substance
m = rate of flow of mercury from the dropping electrode
t = drop time

Once the electrode is set up and adjusted at a satisfactory potential the terms m and t become fixed, and for a particular substance, for example, dissolved oxygen, n is a constant and D varies only with temperature and to a slight extent with the nature of the solution.

The electrode can consequently be calibrated at constant temperature to conform to the following equation:

$$C = K\ (d - d_0) \qquad (2)$$

where

C = concentration of oxygen in p.p.m.
d = galvanometer deflection at x p.p.m. of D.O. (a measure of the current flow)
d_0 = galvanometer deflection at 0 p.p.m. of D.O.
K = a calibration constant

The term d_0 is the so-called "residual current," which indicates the presence of traces of substances reducible at potentials lower than that for oxygen, and also includes condenser current. As will be shown, d_0 is small, constant, and for the most part negligible, in water and domestic sewage. It is readily determined during calibration. Under these circumstances, the measured current yields directly the concentration of D.O., and the major problem remaining is the selection of the potential at which this current shall be measured. This paper is concerned with the selection of that potential and with the evaluation of other factors affecting the results.

Apparatus Required

The basic apparatus required consists of an electrode system comprising a capillary fed from a mercury bulb, and a reference electrode. A potentiometer and source of direct current is used to apply a measured potential across the electrodes, and the current produced is measured by a galvanometer. This equipment is sold as a complete unit by several manufacturers, in various degrees of elaboration. In these studies, for example, the apparatus used was that manufactured by the Fisher Scientific Company. The equipment may also be assembled at considerably less expense from individual parts, by anyone possessing some skill with electrical devices. The set-up described by Ingols is a good example of such assembly.

Selection of Electrode System

The cathode of the electrode system is the dropping mercury electrode itself; connection may be made to the mercury bulb feeding the capillary, or through a side-arm attached to the capillary. The anode may be the mercury pool formed at the bottom of the cell, or a standard calomel half cell may be used. The authors agree with Ingols in the selection of the saturated calomel cell for this purpose, as it offers many advantages. The necessity of a mercury pool is eliminated and there is no effect of halide concentration on the cell potential, as is the case with the mercury pool anode. Moreover, the calomel electrode may be mounted in a single unit in close proximity with the dropping mercury electrode. This not only provides great convenience in operation but greatly reduces the total resistance of the system—an important advantage in making measurements in water and sewage, in which the concentration of electrolytes is relatively low. Large cell resistances tend to shift the apparent potentials at which reduction takes place.

Cell Construction and Procedure Used in Investigations

A diagram of the cell used in these studies is shown in Figure 1. A short length of marine barometer tubing was used for the capillary of the dropping mercury electrode. Size and shape of the vessel are immaterial, and in the form shown the system may be inserted into many types of vessels. For purposes of calibration, it is convenient to use a vessel large enough to permit determination of dissolved oxygen by the Winkler method following the measurement with the electrode.

In the investigations, the experimental procedure was generally as follows:

A solution of the desired dissolved oxygen concentration, produced by

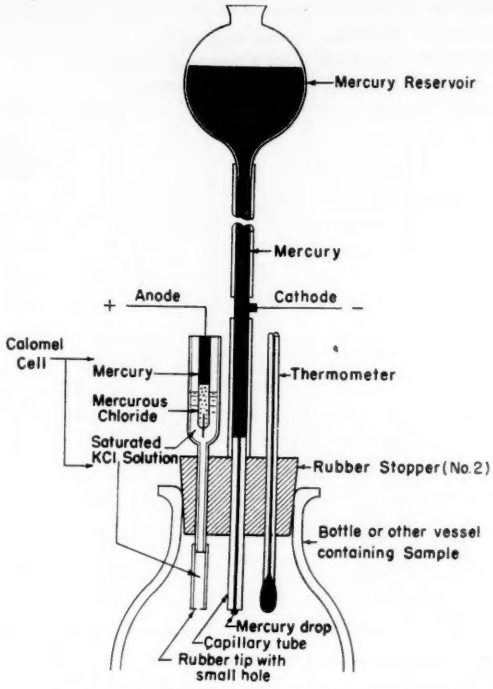

FIGURE 1.—Assembly for determination of dissolved oxygen in liquids by means of the dropping mercury cathode. For the determination, the assembly is immersed in the solution.

bubbling oxygen, air or nitrogen into water or sewage, was placed in the cell, and the stopper inserted, excluding air bubbles. The potentiometer was standardized, and the galvanometer set to zero. Then the applied potential was increased by regular increments from zero to the potential of hydrogen discharge, reading the galvanometer deflection at each potential. In this way, the current-voltage curve for oxygen was determined and plotted. The dissolved oxygen was then determined on the same sample by a modification of the Winkler method suitable to the solution under test.

The results obtained and conclusions drawn are discussed in the sections of the paper which follow.

Characteristics of the Dissolved Oxygen Wave

The reduction of dissolved oxygen at the dropping mercury electrode proceeds in two steps. In the first step, hydrogen peroxide is formed, and in the second, the hydrogen peroxide is converted to water. The amounts of these reaction products are very minute. The current-voltage curves produced show a corresponding two-stage character; examples are shown in Figures 2 and 3. The crest of the first wave is reached at a potential (against the saturated calomel cell) of 0.6 to 0.8 volt; the crest of the second varies considerably with dissolved oxygen concentration, and will range from 1.6 volts at normal values of D.O. to

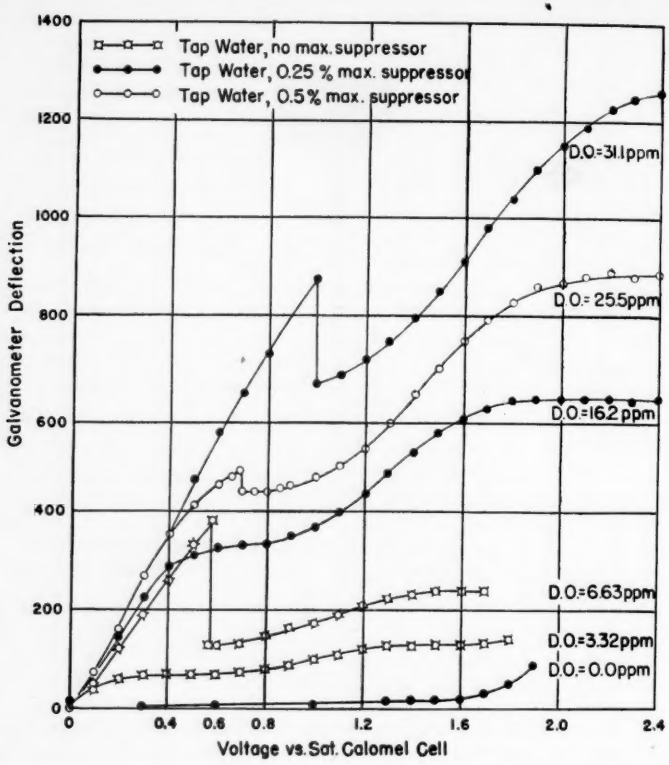

FIGURE 2.—Maxima and their suppression in tap water. Maximum suppressor is 24 gm./liter dextrose broth (Difco).

values as high as 2.4 volts for very high D.O. concentrations.

The first wave, under certain conditions, is obscured by a large increase in current which is believed to be due to absorption of reducible material on the surface of the mercury. This phenomenon occurs in connection with reduction waves of many substances other than oxygen. The current subsequently falls back to its normal value, proportional to the oxygen concentration. The upper curve in Figure 2 shows one of these so-called "maxima" at 1.0 volt; in this case the rise had been partially suppressed by the addition of dextrose broth. These maxima might be troublesome in making determinations, but they can be suppressed easily, as will be shown. The residual current, obtained in the absence of dissolved oxygen, is also shown in Figure 2. In a tap water or sewage containing little in the way of substances reducible below the potential at which oxygen is reduced, it is obviously small.

Suppression of Maxima

The maxima which appear in the first wave of a current-voltage curve for oxygen may interfere with the determination of dissolved oxygen. They may, however, be readily suppressed by small amounts of adsorbable substances, such as proteins, carbohydrates, dye-stuffs, soap, and the like. The use of dextrose broth as a "synthetic sewage" in other work suggested its employment to sup-

press maxima. The composition of the broth in grams per liter is as follows:

Beef extract	3.1
Tryptose	10.5
Dextrose	5.2
NaCl	5.2
Total	24.0

The addition of 2.5 ml. of this broth per liter of tap water completely suppressed maxima in samples containing up to 16.2 p.p.m. D.O.; at 31.1 p.p.m. D.O., the maximum was only partially suppressed. Five ml. of the broth per liter suppressed maxima completely up to 22.2 p.p.m. of D.O., but at 25.5 p.p.m. a slight maximum appeared. Examination of the waves shown in Figures 2 and 3 will bear out these statements. It is concluded that 5 ml. of the broth per liter are adequate to suppress maxima in all but the very

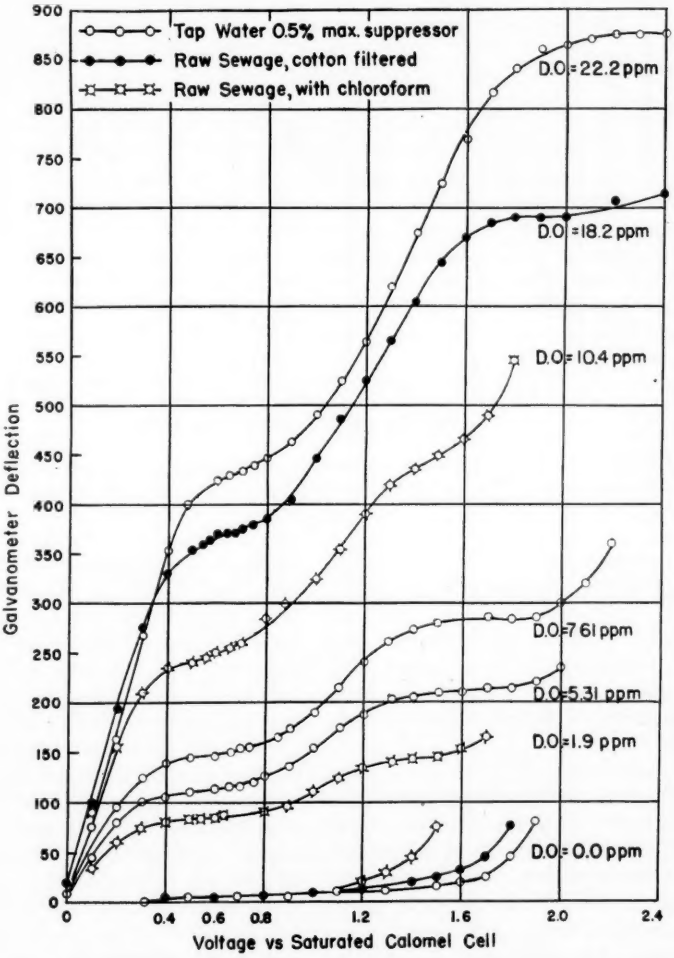

FIGURE 3.—Dissolved oxygen current-voltage curves for tap water and raw domestic sewage.

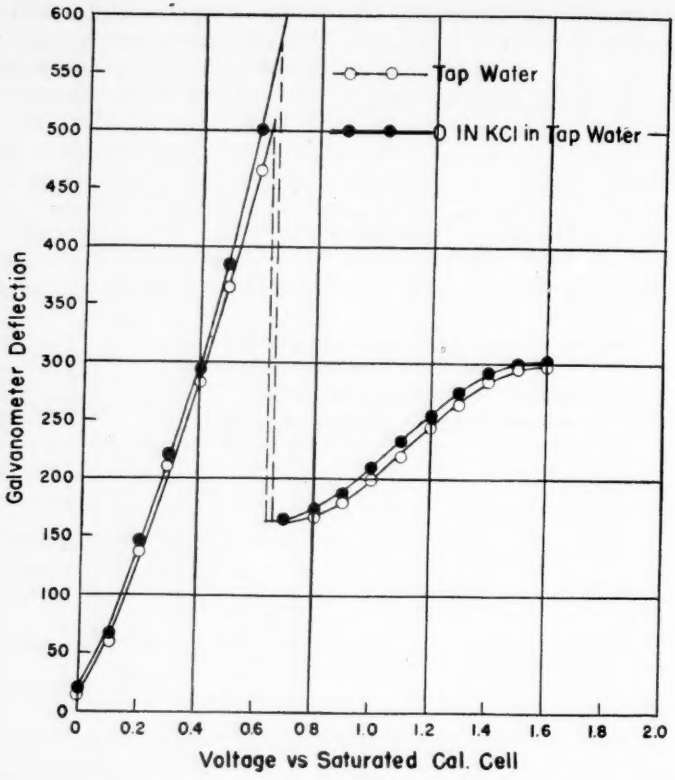

FIGURE 4.—Effect of addition of electrolyte to tap water on the current-voltage curve for dissolved oxygen. The deflection on the flat part of the curve is practically unaffected.

highest oxygen concentrations. It was demonstrated by a number of comparative experiments that the addition of the broth in these amounts does not affect the accuracy of the D.O. determination, nor does it alter the calibration curve of the instrument (Figure 5).

The conclusion reached by Ingols that sewage yields smooth current-voltage curves without the addition of a maximum suppressor was confirmed in this investigation. In no instance did the current-voltage curves for sewage samples exhibit any trace of a maximum. The addition of a suppressor may therefore be omitted in determinations of dissolved oxygen on sewage. In tap water, contrary to the findings of Ingols, it is possible to obtain curves which are smooth and reproducible at all points except in the vicinity of the first wave.

Effect of Electrolytes

In most polarographic determinations it is customary to add a "supporting electrolyte," consisting of some neutral salt, the ions of which are not reducible at the potentials used in the determination. Potassium chloride is most frequently used for this purpose. The function of the supporting electrolyte is to facilitate measurements by reducing the resistance of the cell.

The use of a calomel cell rather than the mercury pool as the anode of the cell system so lowers the resistance of the system that the addition of supporting electrolyte is unnecessary in the determination of dissolved oxygen. However, it is necessary to determine whether or not any electrolyte present in the samples will affect the dissolved oxygen readings. Ingols has suggested that sodium chloride may affect the results obtained at a potential of 1.0 volt, and previous investigators have noted shifts in the current-voltage curves with changing concentrations of inert electrolytes.

In order to evaluate the possible effects of electrolytes, complete current-voltage curves were run with tap water, and with the same tap water plus enough KCl to make the solution 0.01N. Both samples had a D.O. of 8.24 p.p.m. No maximum suppressor was used. The results are plotted in Figure 4, which shows that at the top of both oxygen waves (0.7 volt and 1.6 volts) there is no difference between the two samples. From this and other experiments it has been concluded that any determination of dissolved oxygen based on readings taken on the flat portion of either wave will not be affected by inert electrolytes, at least up to a concentration of 0.01N (750 p.p.m.). Most waters and sewages have concentrations of electrolytes considerably less than this value.

The observation above does not contradict the results of Ingols on the effect of salt concentration, since the authors' results also show an increase in the observed current on the rising parts of the curve. Ingols' observations were made at 1.0 volt, and showed an apparent increase in observed current of as much as 27 per cent due to the addition of 1,500 p.p.m. NaCl. While the authors' results do not indicate such a great effect, there is a definite increase in observed current at 1.0 volt, and at all other points on the rising portions on the curve. This increase has an important bearing on the selection of a potential to be used for single-potential measurements of dissolved oxygen, as shown in the next section.

Choice of Potential for Single-Potential Readings

If it were necessary to run the entire current-voltage curve for each dissolved oxygen determination, the polarographic method would have little to offer. However, it is entirely possible to determine the dissolved oxygen by measuring the current at a single properly selected voltage. The instrument can be calibrated in terms of the relationship between the observed current at this voltage and the dissolved oxygen content of the sample. If the voltage has been properly selected, a straight-line relationship between the two quantities will be observed.

Ingols adopted the single-potential method, and selected 1.0 volt as the potential to be used for measurement. The work of the authors indicates that the choice of 1.0 volt was somewhat unfortunate, since this potential lies on the rising part of the second oxygen wave. In this region slight changes in applied potential and in ionic content of the solution tested produced considerable changes in the observed current.

At potentials which lie on the flat portion of the first wave, better correlations between current and dissolved oxygen are obtained. The flat portion of the second wave changes its position with dissolved oxygen concentration; up to 8 or 9 p.p.m. of dissolved oxygen, the curve flattens at 1.6 volts, but with progressively higher concentrations of dissolved oxygen the second wave shifts to the right. This shift is evident in Figures 2 and 3, which also serve to illustrate the criteria to be used in the selection of a suitable potential for direct measurements.

The apparent increase in the potential at which reduction occurs is

due to the increase in the *IR* (potential) drop in the cell which accompanies the higher diffusion currents produced at higher oxygen concentrations. At any given concentration of D.O., the current at the second wave is approximately twice the current at the first wave; hence the shift with increasing dissolved oxygen is more marked in the second wave. The shift may be minimized by decreasing the resistance of the cell by placing the calomel cell as near as possible to the capillary or by the addition of electrolyte to the solution.

Studies of the waves obtained, together with trial plots of galvanometer deflection against dissolved oxygen content, showed that, as expected, the best correlations are obtained where

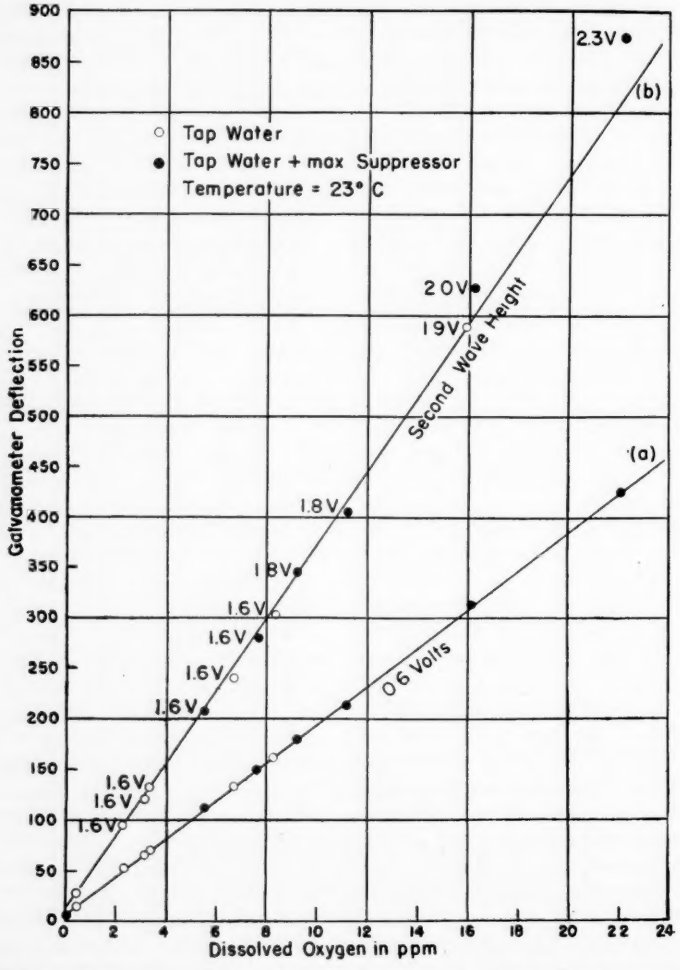

FIGURE 5.—Calibration curves. (a) Calibration curve for dissolved oxygen determination. Galvanometer deflections measured at 0.60 volt against saturated calomel cell. (b) Calibration using galvanometer deflections at second wave. Indicated voltages are for flat portions of the second waves.

the curves are flattest at the top of the first wave, namely at 0.6 volt against the saturated calomel electrode. Figure 5 (line a) is a plot of all values of galvanometer deflection obtained at 0.6 volt against dissolved oxygen concentration as determined by the Winkler method. The temperature of measurement was 22°–24° C. The values include those obtained with and without maximum suppressor. The excellence of the linear relation obtained is evident.

The equation of the line is

$$C = 0.0525\ (d - 5)$$

where C = dissolved oxygen in p.p.m.
d = galvanometer deflection.

The value 5 represents the residual current at zero dissolved oxygen, and is obtained either by direct measurement or extrapolation to zero. Figure 5 is typical of the calibration curve that would be set up for any dropping mercury electrode which was to be used to determine dissolved oxygen. Only two points are required for the initial calibration.

With the apparatus used, the precision of the determination at 0.6 volt was ± 0.03 p.p.m. below 5 p.p.m. of dissolved oxygen, ± 0.05 p.p.m. between 5 and 10 p.p.m., ± 0.13 p.p.m. between 10 and 25 p.p.m., and ± 0.25 p.p.m. above 25 p.p.m. The precision of the values is therefore quite comparable to that obtainable by the Winkler method.

It is not possible to use any single potential for measuring all ranges of dissolved oxygen concentration by means of the second wave, although there would be certain advantages in the use of the second wave for determinations in waters, notably the elimination of the necessity for a maximum suppressor. If the range of dissolved oxygen to be expected is known, and limited, a single voltage can be selected. For dissolved oxygen concentrations from 0 to 9 p.p.m. the instrument used by the authors gave the best results at 1.6 volts. The use of the second wave is attractive for making measurements in continuous-flow channels, tanks, and the like. For this reason a calibration curve for the second wave height as related to dissolved oxygen concentration is included in Figure 5, line (b). The potential given for each point is that at which the flat portion of the wave occurs, and is consequently the one recommended for use at the particular dissolved oxygen concentration.

Effect of Temperature

It is well known that the diffusion current obtained for any given concentration of reducible substance increases as the temperature increases. It is therefore necessary to make all measurements at the temperature of calibration or to establish the quantitative effect of temperature on the diffusion current. The work of Baumberger (2) indicated an increase of about 2 per cent per degree centigrade in the diffusion current in the region of 20° C. Manning (4) used a temperature correction of 1.6 per cent per degree centigrade, without specifying a reference temperature.

Measurement of the effect of temperature was made in the present studies by determining the diffusion current at 0.6 volt for single samples of known dissolved oxygen content which were progressively varied in temperature. The results are shown in Figure 6a. The galvanometer deflection (diffusion current) varies linearly with temperature over the range of temperatures and oxygen concentrations studied.

In Figure 6b, the slopes of the lines in Figure 6a are plotted against the galvanometer deflection at 20° C. in order to determine the relative magnitude of the temperature effect.

In the temperature range 0–35° C., each degree centigrade of temperature change produces a corresponding

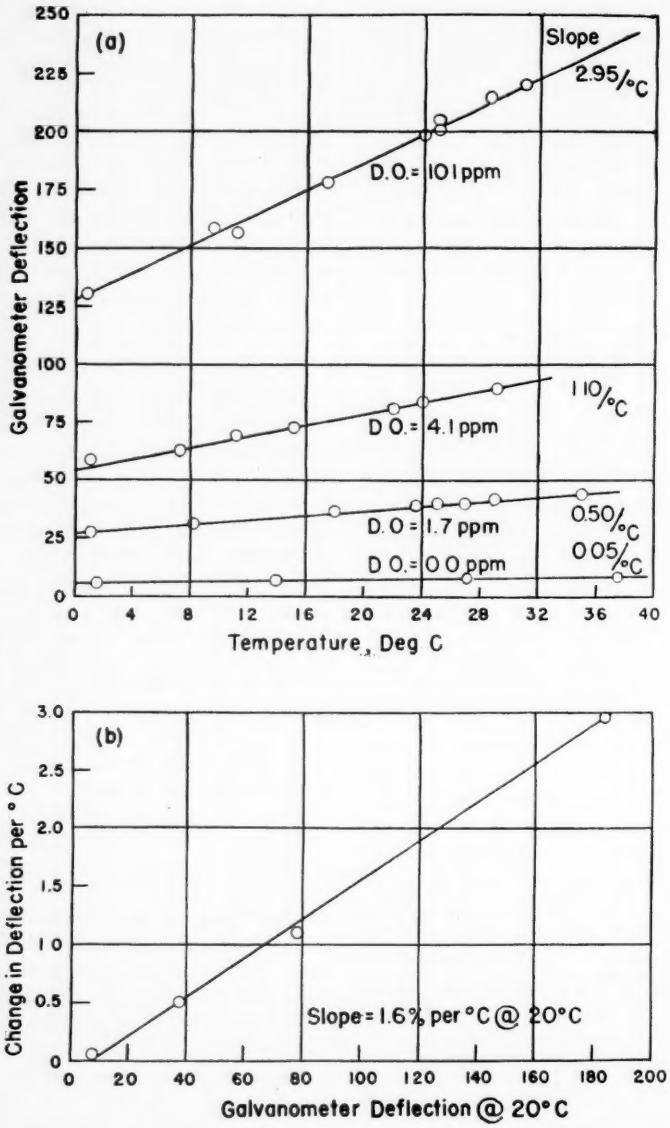

FIGURE 6.—Effect of temperature. All determinations made at 0.60 volt against saturated calomel cell. (a) Effect of temperature on galvanometer deflection at oxygen concentrations noted. (b) Determination of temperature correction in terms of deflection at 20° C.

change in the net current (total minus residual) equal to 1.6 per cent of the net current at 20° C. This value is independent of dissolved oxygen concentration, at least up to 10 p.p.m.; no observations were made beyond this point.

In terms of the equation for calibration, this may be expressed as follows:

$$C = K_{20}\ [1 - 0.016\ (T - 20)]\ (d - d_0) \quad (3)$$

where

C = concentration of oxygen in p.p.m.
d = galvanometer deflection at $T°$ C. for x p.p.m. of D.O.
d_0 = galvanometer deflection at $T°$ C. for 0 p.p.m. of D.O.
K_{20} = calibration constant obtained at 20° C.

Effect of Head of Mercury and Drop Time

In practical measurements it is essential to maintain a constant head of mercury over the capillary during all current-voltage determinations, since the current varies as the square root of the effective pressure of the mercury on the capillary. The "drop-time," or average life of the mercury droplet, should also be maintained relatively constant, and should be recorded in any calibration. However, small changes in drop-time are unimportant, since its effect on the diffusion current is proportional to the one-sixth power of the time. In these studies the drop-time varied between 2 and 4 sec. without materially affecting practical determinations. The drop-time should not be adjusted between calibrations by altering the height of the mercury column above the capillary.

Special Features of Determinations in Sewage

Current-voltage curves obtained from domestic sewage, with or without the addition of chloroform as a preservative, are substantially identical as to form and location of the flat portions of the waves with those obtained from tap water. The only difference observed is the absence of maxima, which are completely suppressed by substances in the sewage. Some current-voltage curves obtained with domestic sewage at various oxygen concentrations are shown in Figure 3. The potential recommended for measurement is 0.6 volt, the same as that for tap water.

A series of cotton-filtered raw domestic sewage samples was adjusted to unknown dissolved oxygen concentrations, which were determined by the electrode, using the calibration curve of Figure 5, and then by the Winkler method. The same samples were used in both determinations.

TABLE I.—Comparison of Determinations of Dissolved Oxygen in Raw Domestic Sewage

(All results in p.p.m.)

Electrode	Modified Winkler Method	Difference
1.0	0.4	0.6
2.0	1.6	0.4
5.1	4.8	0.3
5.3	4.9	0.4
5.8	5.4	0.4
6.3	5.5	0.8
8.4	6.7	1.7
8.3	7.9	0.4
9.8	9.6	0.2
11.9	10.6	1.3
12.9	12.5	0.4
14.2	13.3	0.9
15.7	14.3	1.4
17.7	18.2	−0.5
22.0	21.0	1.0
	Average	= 0.7 p.p.m

The results are shown in Table I. It is recognized that the Winkler method tends to give low values in sewage; in these studies an attempt was made to minimize the errors known to occur in the Winkler test when considerable organic matter is present, by using the alkaline-iodide solution of Pomeroy and Kirschman (5) and the short period of alkalization. Nevertheless, determinations by the Winkler method gave low results compared to the

dropping mercury electrode. In the absence of a method of known reliability for the determination of dissolved oxygen in sewage, one cannot tell which set of figures is closer to the true value. However, the type of deviation observed is that to be expected if the known sources of error in the Winkler method are operative. If one desires determinations which will agree with those by the Winkler method, a separate calibration curve for sewage can be used.

In domestic sewage the residual current observed was no higher than that for tap water. Domestic sewage apparently does not contain substances reducible at potentials below the reduction potential of oxygen. However, it would be well to point out that this may not be true of sewage containing industrial wastes, which may quite possibly contain interfering substances. In such sewages, a complete study of the entire current-voltage curve at known concentrations of dissolved oxygen will be required to establish the presence or absence of interference, and the possibility of correction for, or avoidance of, the interference. In connection with this, attention is called to the work of Ingols, who found that zinc and arsenic interfere at 1.0 volt, but that nitrate and nitrite do not. Zinc would not interfere at 0.6 volt, the potential selected by the authors, but the possibility that other substances present in industrial wastes may interfere should not be overlooked. Some possible interfering substances are: copper, lead, ferric iron, chromate, and available chlorine.

Practical Suggestions

The technique of determinations with the dropping mercury electrode is not one that can be acquired in an afternoon's work. The first step is to become familiar with the operation of the equipment. This may be done by running a number of complete current-voltage curves against solutions of known dissolved oxygen content, ranging from zero to the maximum desired. In the course of this work one becomes familiar with the characteristics of the apparatus, the form of the waves, the location of the flat portions, and also any special features of the waters or sewages studied. The magnitudes of residual currents encountered will be apparent from these studies. Furthermore, if the particular equipment used brings out the flat portions of the waves at potentials different from those used by the authors, the operator can select his own potentials for his practical measurements. In no case should potentials which lie on the rising parts of the waves be used for analyses.

After the operator has become thoroughly familiar with these points, he may proceed to the selection of a suitable voltage for single measurements, which may not necessarily be the same as that used by the authors. By using samples of the water or sewage in which the dissolved oxygen content is varied by elimination or addition of oxygen, he will then establish a calibration curve of dissolved oxygen versus observed current for this potential. If a high degree of accuracy is desired, the calibration curve should be rechecked at reasonable intervals; a single measurement at a known dissolved oxygen concentration will generally suffice. In the authors' studies, the calibration remained constant for a week or more during regular use of the instrument. The tip of the capillary tube should be cleaned by immersion in 1N nitric acid. When not in use, the capillary tube should be immersed in mercury and should never be emptied of mercury.

Summary and Conclusions

1. Determination of dissolved oxygen in water and sewage by the polarographic method offers a number

of advantages that should be of interest to research workers and practical analysts. The theory of the method is complex, but its application is largely a matter of the acquisition of the necessary technique.

2. The authors recommend for general use a potential of 0.6 volt against a saturated calomel electrode; this potential lies on the flat portion of the first oxygen wave. The addition of a maximum suppressor is necessary for determinations in water, but not for determinations in sewage.

3. For continuous observation in water, the second wave may be used to avoid the necessity for maximum suppression, but the potential to be used will vary with the range of oxygen concentrations to be expected. For the ranges normally encountered, the recommended potential is 1.6 volts.

4. The effect of extraneous electrolytes is negligible at the potentials recommended for use. Residual currents are very small in ordinary waters and in domestic sewage. They are eliminated by establishing calibration curves for the water or sewage in question, using known dissolved oxygen concentrations.

5. Corrections for the effect of temperature may be made by means of a simple formula. The variation of readings with temperature is linear over the range 0–35° C., and amounts to 1.6 per cent of the reading at 20° C., per degree centigrade change.

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INSTITUTE OF SEWAGE PURIFICATION SUMMER CONFERENCE

All Federation members who will be in England next summer are cordially invited to attend the 1949 Summer Conference of the Institute of Sewage Purification, which is one of the Federation's two English member associations. This invitation has been extended through W. F. Freeborn, Hon. Secretary of the Institute. The Conference will be held at Herrogate, June 20–22, 1949.

Mr. Freeborn will welcome inquiries concerning the Institute's 1949 Summer Conference from anyone planning to visit England. He will also be glad to assist Federation members with arranging visitation schedules or inspection trips to English sewage treatment works. Mr. Freeborn's address is:

34 Cardinal's Walk
Hampton-on-Thames
Middlesex, England

THE "WIDE BAND" AIR DIFFUSION SYSTEM [1]

By Frank C. Roe [2]

Eastern Manager, Chicago Pump Company, Chicago, Ill.

The problem of obtaining the most effective, economical and, at the same time, the most practical equipment for sewage aeration has confronted sanitary engineers ever since conception of the activated sludge process about 35 years ago. In fact, one could prepare an extensive history outlining the many interesting methods and types of equipment which have been tried.

The purpose of this paper is to give a concise picture of the "Wide Band" aeration system introduced by the Chicago Pump Company during the past decade.

Development

With very few exceptions, all of the aeration ideas tried will accomplish reasonably good results, but the variation in total cost can be extremely wide for any given degree of treatment. This experience led to the early controversies between the proponents of diffused air and the equally sincere advocates of mechanical aeration. Various types of equipment using both methods could do a job, over which individuals became enthusiastic, but the overall cost picture did not become apparent until operating experiences were extensive.

That situation continued until now both mechanical and diffused air methods are considered efficient. But other factors, primarily that of plant capacity, control the selection of equipment for any given job.

Parenthetically it can be observed that the trend in selection of mechanical aerators has been for smaller and smaller plants as diffused air equipment has become more efficient. It is conceivable that diffused air may some day be not only the most effective, but also the most economical and practical method for even the smallest plant.

Getting back to the concept that practically all equipment has done the job after a fashion, it must be admitted that a great deal of oxygen is secured at the surface of aeration tanks. But simultaneously there can hardly be a doubt that the size and method of introduction of air bubbles has a definite effect on efficiency. The work of Scoular and Watson in England in 1934 on this point is corroborated by the extensive work of Redding at the Massachusetts Institute of Technology in 1938 and by general experience at treatment plants. For example, the substitution of porous diffusers giving small bubbles, in place of perforated pipe which delivered large bubbles, resulted in much lower air requirements at such places as San Marcos, Texas and Morristown, N. J.

Acceptance of the fact that oxygenation is induced both by the air bubbles and by surface aeration thus reduces the problem to the finer details of equipment type and arrangement, with the operating experience factor looming large. At this point, the one important prerequisite of any method must be borne in mind: *It must function in a manner that will constantly maintain all sewage and sludge solids in good circulation and contact with the two sources of oxygen.*

It took only a few years to establish porous ceramic plates, and later porous tubes, as efficient and practical media for the diffusion of air bubbles. During the subsequent experience it became

[1] Presented at Metropolitan Section Meeting of the New York State Sewage Works Association, New York City, June 9, 1948.

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apparent that small-pore diffusers clogged "sooner rather than later." A material with permeability increased from about 15 to 40 was therefore developed to minimize the trouble and expense of cleaning and/or replacement. Incidentally, Beck's work in 1935 indicated that air bubble size was not increased by that particular development, so presumably there was no decrease in oxygenation efficiency. A later permeability increase from 40 to 80 and even to 120 has been tried to reduce clogging from a dirty air supply, but the bubbles are slightly larger and efficiency appears to be lower.

"Wide Band" Diffusers

Solving the operating problem of diffuser servicing was the primary objective in the development of the "Wide Band" system. The secondary objective, of almost equal importance, was to improve the method of introducing air and thus increase efficiency.

The selection of tube type diffusers for both stationary and "swing" equipment was logical to meet the first objective in the face of experience. They are simple to remove, clean and replace without breakage. They are no less efficient than diffuser plates, and the installed cost is much lower. The last two incidental points have been argued, but the preponderance of operating and cost data will prove their correctness.

To meet the second objective of improving efficiency, the "Wide Band" principle was adopted and made economically feasible by locating the diffuser tubes at right angles to the tank side walls and attaching them to the air headers (Figure 1). The theory of this principle is that a larger volume of liquid and air bubbles is continuously rising, as a result of air

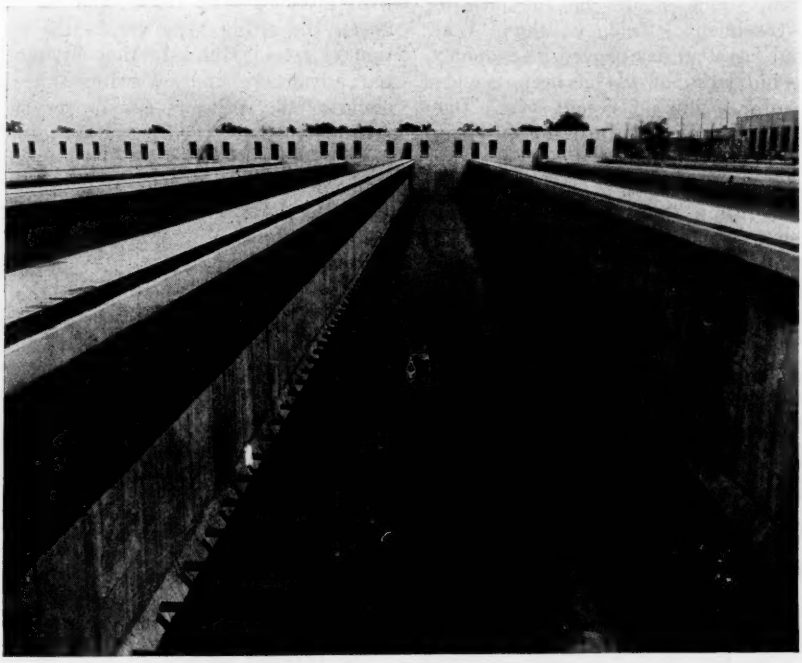

FIGURE 1.—Stationary "Wide Band" diffusers at Gary, Ind. sewage treatment plant.

lift, than when the same amount of air is introduced to the liquid in a narrow band. Moreover, the improved tube spacing results in better air distribution, i.e., less coalescence of air bubbles, than occurs with closely spaced diffusers.

Scale model glass tank operation definitely shows higher bottom velocities and more rapid displacement of tank contents than is provided by other methods functioning at the same rate of air diffusion. To check this in practice and to establish bases of design, research engineers donned diving suits and spent a good many hours in the tank bottoms of early installations at Cleveland, Ohio, and elsewhere.

Experience

The acid test is in plant performance. Easy access of tube diffusers for servicing is so obvious that it needs only mention. On the basis of cost (for air or power) per unit of B.O.D. removal, which should be the measure of treatment efficiency, the "Wide Band" system has proved its economy. One indication of this has been its wider acceptance during recent years than all other types of diffuser equipment or methods combined. For example, every large municipal project employing aeration that has gone into construction since the war (Boston Nut Island, Philadelphia, N.E., Columbus, Oklahoma City, Phoenix, and Los Angeles) will use the "Wide Band" system. The number of additional installations which are designed but held in abeyance during this period of excessive construction cost runs to a hundred or more.

Incidentally, the recommendation of "Wide Band" swing diffusers by Greeley and Hansen for an addition to the Madison, Wis. plant is of interest. The existing plant utilized diffuser plates on the tank bottom. Swing diffusers are elevated 2 ft. above the bottom, but it is obviously desirable to operate them in connection with plates in the existing tanks at a uniform blower pressure. This meant deeper and wider tanks for new construction, thus effecting a welcome saving in construction cost.

Actual tests on a plant scale are difficult to evaluate numerically because of inequality factors, but they have generally corroborated laboratory results and have proved the expected operating advantages of the "Wide Band" system. In one case the oxygen demand was reduced to a satisfactory level in approximately 80 per cent of the time required by two different systems of plate diffusers.

Of perhaps greater importance was the fact that the equipment was in service continuously, whereas the other systems were out of operation up to 25 per cent of the time for cleaning.

Swing Diffusers

Up to this point, the "Wide Band" system of tubes has been discussed with no particular discrimination between the swing type versus the stationary type. But a further outstanding advantage of the swing type is obvious: the diffusers can be serviced frequently and speedily without tank dewatering (Figure 2). This means a big saving in operation expense and a tremendous saving in capital expenditure because no standby capacity is essential.

It seemed likely during initial development that swing diffusers would be more costly than the stationary type and that selection would be controlled by balancing the cost difference against the saving in costs of servicing and standby capacity. However, improvement in the design of swing equipment and the increasing demand for it, coincident with greatly increasing cost of labor for installing stationary diffusers, has now brought the installed cost of swing diffusers below that of stationary diffusers.

Of perhaps greater interest on the subject of first cost installed is the

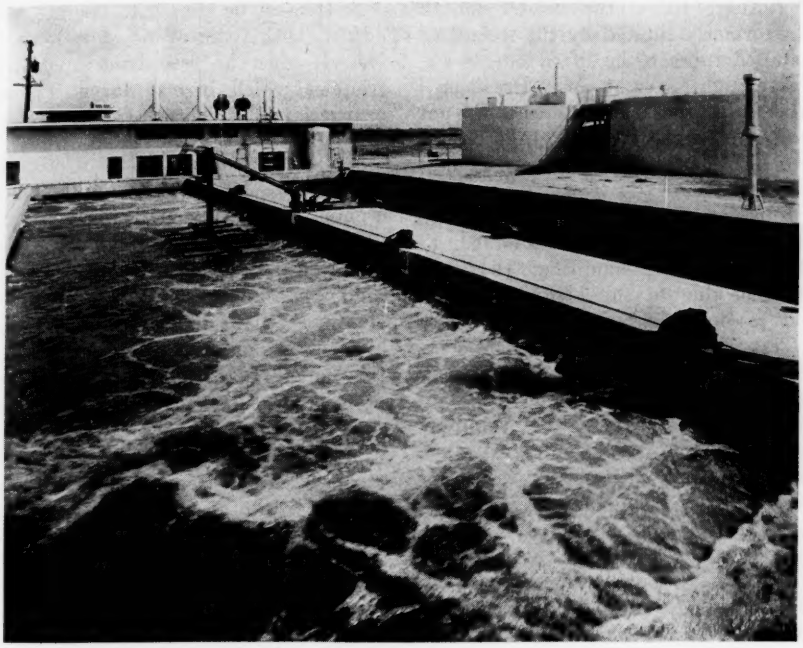

FIGURE 2.—Swing diffusers, Oildale, Calif. sewage treatment plant.

fact that on the basis of recent bids, swing diffusers are about equal to two rows of plates, in large installations. In small installations the cost equalizes somewhere between the cost of two rows and three rows of plates. The installed cost of swing diffusers at the Chicago Southwest plant in 1945 was approximately $33 per foot of tank length. The greatest difference, as previously suggested, was in the labor increment for actual installation. Each system was equal in capacity, although the swing diffusers provided the widest band of air distribution.

Other advantages of the "Wide Band" system and of swing diffusers in particular are:

1. The wide air band makes it possible to use tanks of maximum cross section; hence, lower construction cost.
2. Each tube has individual orifice control which assures uniformity of diffusion between units, even in the rare instance of a tube breakage.
3. Tubes can be changed easily and with no extra expense so that variations in aeration are possible to meet oxygen demand requirements (e.g., tapered aeration) or so that uniform aeration may be practiced, as desired.

New "Precision" Tubes

The increasing use of swing diffusers has naturally led to refinements to improve effectiveness or reduce cost. The most outstanding of these is the recently anounced "Precision" diffuser tube which consists of a "Saran" plastic cord wound tightly and closely around a corrugated stainless steel core.

The primary objective of this particular development was to decrease diffuser weight so that maximum length headers could be used for each swing diffuser. For the influent end of tanks employing the tapered aeration principle, or where unusually strong sewage requires an exceptional number

of diffuser tubes, the header length was formerly limited by the weight of installed tubes to be lifted out.

The light weight of "Precision" tubes, plus the fact that they do not require assembly with adaptors on the job, also materially reduces the cost of installation.

Further advantages of "Precision" tubes appear to be: (a) no danger of breakage during handling, (b) easy to clean due to thin diffuser media, and (c) low pressure loss.

Test installations have been in service for more than a year and many installations are now being made in plants. Among these are Abington, Pa., Phoenix, Ariz., Columbus, Ohio, and final tank channels at the New York Ward's Island plant.

Conclusion

The "Wide Band" system of air diffusion meets the fundamental specifications which engineers and operators would like to apply today to all sewage plant equipment. These are:

1. It must provide satisfactory results at a minimum power cost.
2. It must be simple to operate and adjust, with little or no shut-down.
3. It must be free from operating troubles which involve large expense or excessive replacement.

The development of this system to its present stage plus the changed economy in construction costs has established activated sludge treatment as lower in total cost (initial and annual) than any other type of complete treatment plant throughout the range of medium-small to large capacity. To this advantage may be added those of smaller site, closer location and freedom from nuisances.

The improvements herein described have also increased the efficacy and economy of other important aeration applications beyond activated sludge, such as aerated grit chambers, preaeration, "modified" aeration, raw sludge aeration (with return), and others. The popularity of these applications will increase as the high aeration or treatment efficiency and the low cost of installing and operating the equipment is realized.

Industrial Wastes

LABORATORY STUDIES ON EFFECT OF ALKALI-CHLORINATED CYANIDE, CASE HARDENING, COPPER AND ZINC PLATING WASTES ON AEROBIC AND ANAEROBIC SEWAGE TREATMENT PROCESSES

By G. M. Ridenour

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The results of laboratory studies on the effect of cyanide case hardening, copper and zinc plating wastes, pretreated by calcium polysulfide, on the activated sludge and sludge digestion processes of sewage treatment have previously been given (1) (2). These results showed that although these treated wastes possessed a certain toxicity to these two types of sewage treatment, the degree of toxicity was not so great that discharge of the waste into the sewage entering sewage treatment plants was precluded, provided discretional analysis was made of the individual situation particularly with reference to the potential sewage dilution before reaching the plant.

An alternate method of metal plating wastes treatment, for removal of the cyanides and heavy metals, now increasing in popularity because of economical and operating advantages, consists of alkali-chlorination of the wastes. The question of toxicity of these treated wastes is of the same interest as the polysulfide treated wastes in connection with biological treatment units. In addition it is desirable to know whether the alkali-chlorine treated wastes are more or less toxic than those by the calcium polysulfide treatment, and what concentrations might be tolerated by the aerobic and anaerobic sewage treatment processes. This information is pertinent in that quite often the only outlet for the industrial wastes is through the domestic sewers. This report gives the results of a laboratory study of the effect of these alkali-chlorine treated metal plating wastes on two representative types of biological sewage treatment units, activated sludge and sludge digestion.

Character of Wastes

The wastes used in these studies were derived by treatment of the concentrated case hardening, copper and zinc cyanide solutions used in the metal plating tanks. The untreated metal plating solutions were typical solutions, and contained sodium cyanide, caustic soda and the metal cyanide. The carburizing solution consisted of sodium cyanide, barium chloride, sodium chloride, potassium chloride and strontium carbonate. The equivalent cyanide content of the metal plating solutions was 5 per cent expressed as NaCN. The carburizing solution contained 2½ per cent cyanide expressed as NaCN.

To represent the treated wastes which would reach the sewage plant, these original metal plating and carburizing salt solutions were treated with an appropriate amount of sodium hydroxide and chlorine. In this treatment the specific chemical reactions taking place have not been exactly

established, but present evidence seems to show that the cyanide is broken down in a two-step reaction, first to cyanate and then to sodium chloride and sodium carbonate. It has also been suggested that ammonium carbonate may be formed as a side reaction to account for the nitrogen, although this is still a matter of doubt. As far as the cyanide is concerned though, the reaction goes, under the proper conditions, to practically 100 per cent completion with a reduction of the cyanide content to less than 1 p.p.m.

The metal ions in the wastes are precipitated either as oxides or carbonates, as shown by the following approximate analysis of the precipitated sludge:

Waste Liquor	Per Cent Sludge in Treated Waste	Composition
Copper Plating	10–14	12 per cent Cu in form of cupric oxide and basic copper carbonate, and large amount of NaCl crystals
Zinc Plating	2–3	60 per cent Zn, primarily in form of zinc carbonate
Carburizing Solution	7–9	Barium carbonate with small amounts of strontium carbonate

The chlorinated supernatant liquor of the treated sludge contained, in addition to the NaCl and Na_2CO_3, the following materials:

	Alkalinity (p.p.m. as $CaCO_3$)	Chlorides (p.p.m. as Cl)	NaCNO (p.p.m.)	NaCN (p.p.m.)	Metal (p.p.m.)	pH
Copper Plating	78,000	183,000	0	1	1-Cu	11.8
Zinc Plating	90,000	190,000	1200	1	5-Zn	11.0
Carburizing Solution	72,000	183,500	5000	1	? Ba	11.6

It is evident from these analyses that while the cyanide content of the wastes has been reduced to a low level of toxicity, the metal ions, alkaline materials, and salts in both liquor and sludge, as well as the cyanate in the case of the zinc and carburizing solutions, might create an added toxicity factor. This seems particularly so in the whole waste, which includes a relatively high concentration of metal ions in the treated waste liquor sludge. A possible additional factor, unfavorable to biological processes, is the high pH of the wastes, particularly if the buffering characteristics would require high dilution to offset the alkaline effect. Waste acids from other operations in the plant may often be used, however, to offset this alkaline effect.

It is with respect to these various aspects that the effects of the wastes were investigated on the processes of (a) activated sludge and (b) sludge digestion, the former to represent the aerobic and the latter the anaerobic type of sewage treatment. The effects of each: (1) the entire wastes including the sludge and (2) the settled fraction or supernatant liquor of the same wastes, were studied. These latter subdivisions of the problem were thought necessary to establish the advisability of eliminating the sludge fraction of the wastes from the sewers if it were found to add an additional toxicity factor.

Method of Study

Both the activated sludge and sludge digestion studies were carried out in a similar manner and with similar equipment used in the previous studies on polysulfide treated wastes (1) (2).

In general, the activated sludge laboratory operation was designed to (1) stabilize the activated sludge before the waste additions were started, (2) observe in parallel operating units the

effect of various concentrations of the three different wastes on the quality of the supernatent liquor and settleability of the sludge, and (3) determine the probability of recovery of purification ability of the sludge in those concentrations where continued daily additions of the wastes were detrimental. Routine operation of the units was carried on by daily addition of sewage in an amount equivalent to a return sludge treatment of 20 per cent. Air was applied in an amount to give a D.O. in the mixed liquor of from 3 to 6 p.p.m. Suspended solids of the mixed liquor varied from 1,500 to 2,800 p.p.m.

The sludge digestion study was designed to simulate as closely as possible, under laboratory conditions, the field operating routine. Briefly, this consisted of adding daily additions of 2 per cent fresh sewage volatile solids (dry basis) to a series of units containing digesting sludge.

The temperature of incubation at which the studies were carried on was 21° C. Increasing increments of each of the three treated plating wastes were added daily to each of three series of

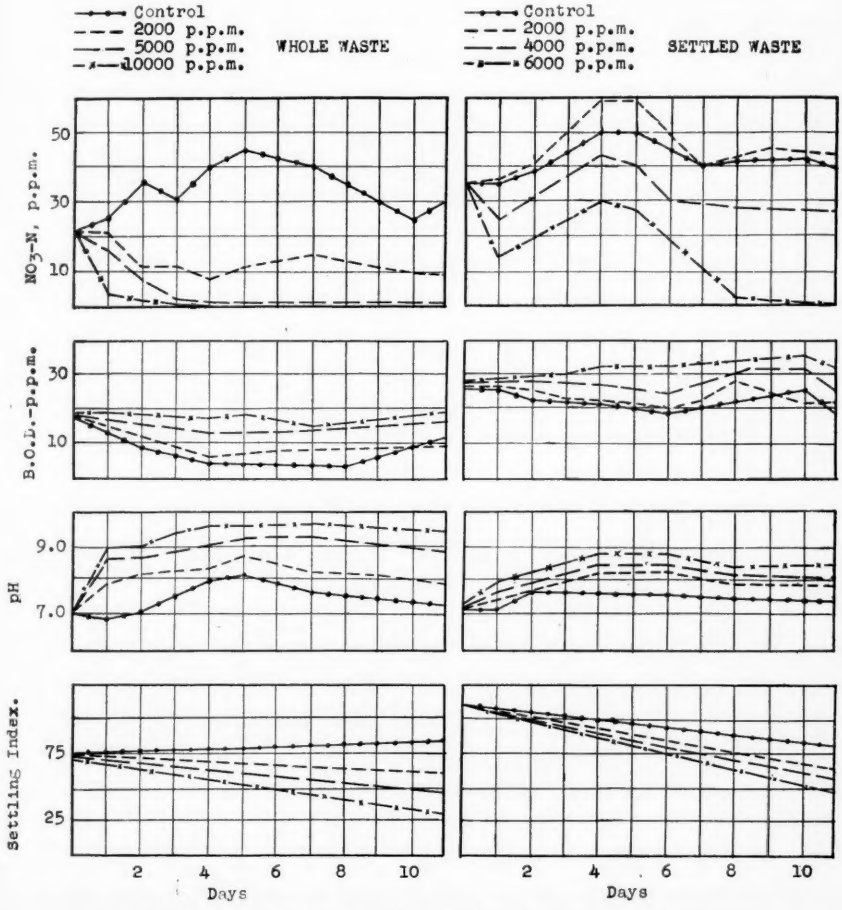

FIGURE 1.—Effect of carburizing solution on the activated sludge process.

these units. The effects of both the settled and whole fractions of the wastes were judged from the amount and rate of gas production.

Part I—Activated Sludge

Results

The effects of the wastes on the activated sludge type of aerobic sewage treatment are shown in Figures 1 to 3 inclusive. Each of these figures show the results of adding only the supernatant or settled liquor of the treated electroplating and carburizing solutions. The former would represent the maximum influence of a poorly settled waste discharged to the sewers, the latter a settled waste. Various concentrations of the waste materials, expressed as parts per million of liquid waste of aeration mixture, are related to their effect on nitrification, biochemical oxygen demand, and pH of the settled supernatant liquor, and the settleability (by "Standard Methods") of the activated sludge floc. The testing period consisted of two parts: first, a period of operation of sufficient

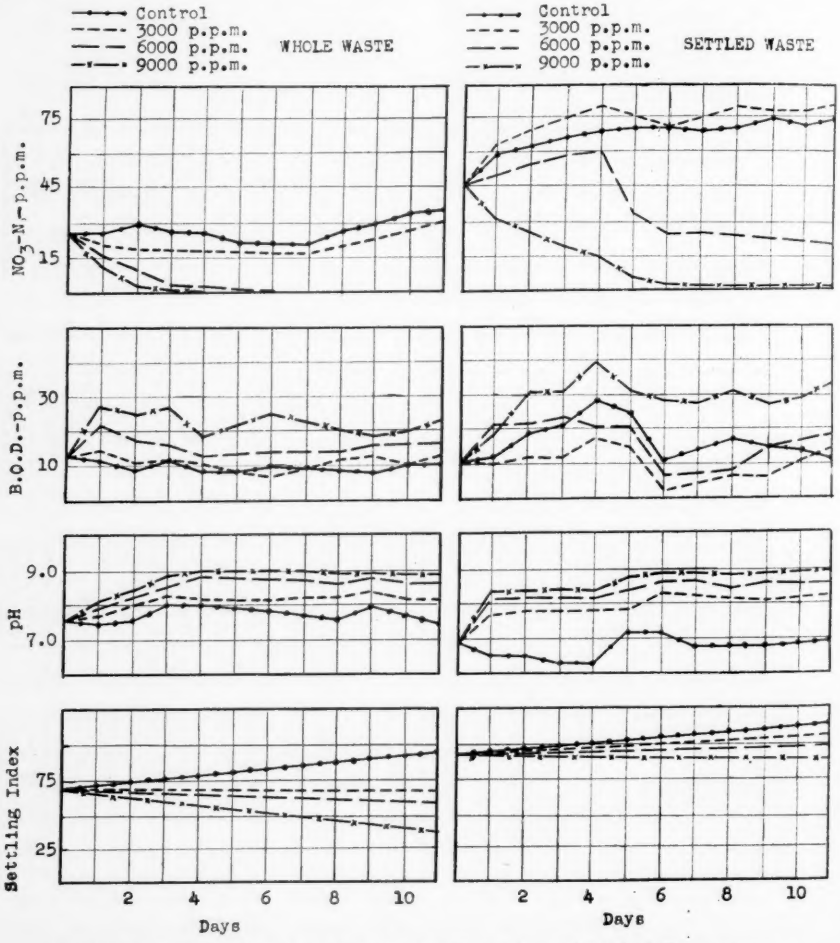

FIGURE 2.—Effect of zinc plating solution on the activated sludge process.

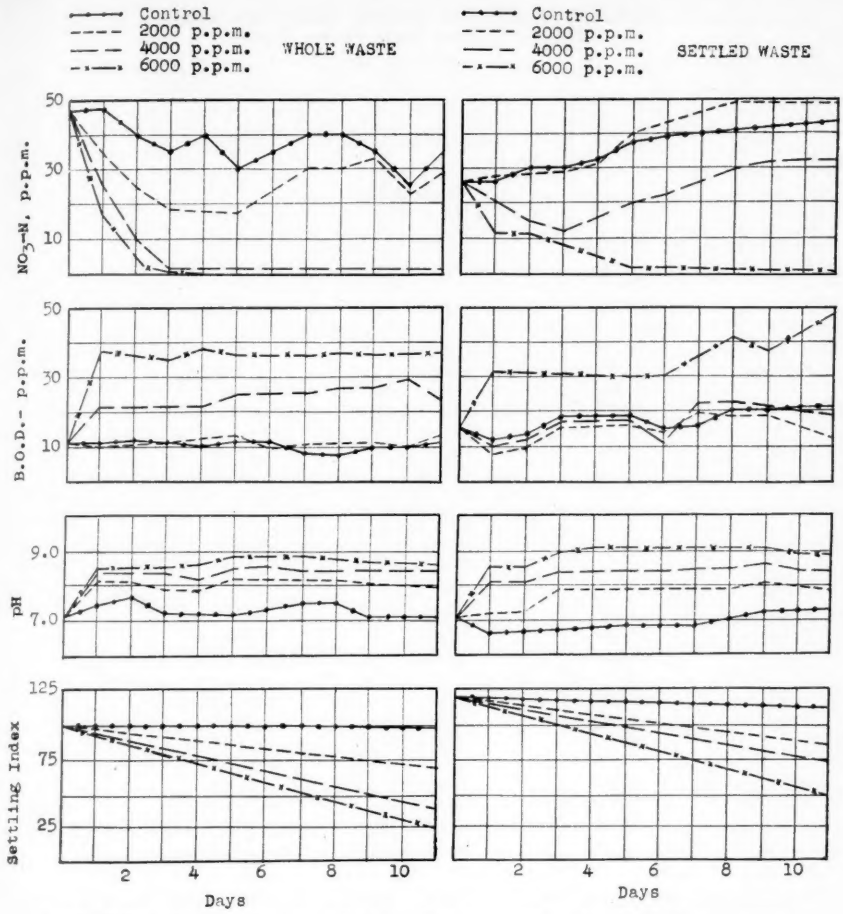

FIGURE 3.—Effect of copper plating solution on the activated sludge process.

length of time to allow the activated sludge mixture to come to an apparent purification equilibrium in the presence of the various wastes and, second, a subsequent period immediately following during which waste additions were discontinued to determine the recovery ability of the sludges which had been exposed to the wastes. This recovery period is shown in Table I. Suspended solids and ash values of the activated sludge mixture in the various units are shown in Table II. Since ammonium carbonate is a major component of the reaction products of the treated wastes, tests were also made on the effect of this material. These results are given in Figure 4.

The effects of the various wastes have been summarized in Table III as related to minimum concentrations that were found to either affect or destroy nitrification. Other related data pertaining to pH, solids and ash of the waste treated units and the controls are also included.

Discussion of Results

The results of this study show in general that with respect to the point

TABLE I.—Recovery of Activated Sludge from Toxic Effects of Treated Metal Plating Wastes

Treated Waste		Days Required for Recovery to Begin		
Used	Conc. (p.p.m.)	NH_3 Reduction	Nitrification	pH Reduction
Whole Waste				
Carburizing Solution	2,000	3 days	6 days	1 day
	5,000	no recovery—15 days	no recovery—15 days	3 days
	10,000	no recovery—15 days	no recovery—15 days	3 days
	15,000	no recovery—15 days	no recovery—15 days	5 days
Zinc Plating Solution	3,000	1 day	2 days	1 day
	6,000	10 days	10 days	2 days
	9,000	no recovery—15 days	no recovery—15 days	3 days
	12,000	no recovery—15 days	no recovery—15 days	3 days
Copper Plating Solution	2,000	1 day	2 days	1 day
	4,000	8 days	10 days	2 days
	6,000	no recovery—15 days	no recovery—15 days	3 days
	8,000	no recovery—15 days	no recovery—15 days	4 days
Settled Waste				
Carburizing Solution	4,000	3 days	5 days	1 day
	6,000	5 days	10 days	3 days
	10,000	12 days	no recovery—18 days	5 days
Zinc Plating Solution	6,000	2 days	2 days	2 days
	9,000	3 days	3 days	3 days
	12,000	4 days	8 days	3 days
Copper Plating Solution	4,000	1 day	1 day	1 day
	6,000	10 days	6 days	3 days
	8,000	no recovery—12 days	no recovery—12 days	4 days

where nitrification was first affected, the tolerance limit of the activated sludge method of sewage treatment to the treated cyanide wastes lay between 2,000 and 6,000 p.p.m. on sludge mixture basis, depending on the type of waste and the fractional component of the waste used. In all cases the whole

Comparison of Tolerance Levels of Alkali-Chlorine and Polysulfide Treated Wastes on Activated Sludge Nitrification

Treated Waste Solution	Nitrification					
	Affected at (p.p.m.)			Destroyed at (p.p.m.)		
	Polysulfide	Alkali-Chlorine		Polysulfide	Alkali-Chlorine	
		Whole	Settled		Whole	Settled
Carburizing	500	2000	4000	2200	5000	6000
Zinc Plating	500	3000	6000	1200	6000	9000
Copper Plating	500	2000	4000	1200	4000	6000

wastes were somewhat more toxic than the settled. This is best illustrated by an examination of Table III. The toxicity threshold limit of all the settled wastes was approximately twice that of the whole waste. This same quantitative relationship did not hold for that point of sludge deterioration where nitrification was destroyed, yet the increased toxicity of the whole waste remains evident.

It is of interest at this point to compare the relative toxicity of the alkali-chlorine treated wastes shown in this study with the same wastes treated by calcium polysulfide in previous studies (1). This comparison is shown in the table at bottom of page 1064.

These data show that the reduced toxicity level of the alkali-chlorine from the polysulfide treated wastes amounts from eight to twelve times for

TABLE II.—Activated Suspended and Volatile Solids in Aerators

Treated Waste		Initial			Final		
Used	Conc. (p.p.m.)	Solids (p.p.m.)	Ash (p.p.m.)	Ash (%)	Solids (p.p.m.)	Ash (p.p.m.)	Ash (%)
Whole Waste							
Carburizing Solution	0	2800	470	17.0	2610	470	18.0
	2,000	2400	412	17.2	2780	780	28.1
	5,000	2200	390	17.5	2890	950	33.0
	10,000	2140	370	17.2	3050	1310	43.0
	15,000	1980	350	17.6	3600	2420	67.2
Zinc Plating Solution	0	2800	480	17.1	3200	590	18.4
	3,000	2880	490	17.0	2930	1140	38.9
	6,000	2740	460	16.9	3390	1580	46.3
	9,000	2840	480	17.0	4150	2600	62.6
	12,000	2780	480	17.2	4480	3130	69.9
	15,000	2700	460	17.0	4790	3440	71.8
Copper Plating Solution	0	1970	340	17.2	2000	360	18.0
	2,000	1960	320	17.2	2370	690	29.1
	4,000	2000	340	17.0	2640	1000	37.8
	6,000	1960	310	16.9	3270	1800	55.1
	8,000	2000	330	16.9	4100	2800	68.3
Settled Waste							
Carburizing Solution	0	2020	300	14.9	2410	240	10.0
	2,000	2000	300	15.0	3290	710	21.7
	4,000	2000	300	15.0	3590	1120	31.2
	6,000	2040	310	15.1	3860	1510	41.7
	10,000	2020	300	14.9	4810	2020	42.0
Zinc Plating Solution	0	1800	220	12.2	1770	200	11.3
	3,000	1760	200	12.0	1840	290	15.7
	6,000	1820	230	12.5	1930	490	25.4
	9,000	1900	240	12.7	2070	530	26.0
	12,000	2020	260	12.8	2240	840	37.0
Copper Plating Solution	0	1540	260	17.0	2200	370	17.0
	2,000	1600	270	17.0	2380	420	17.4
	4,000	1620	280	17.2	2000	500	25.0
	6,000	1560	270	17.1	2010	560	27.2
	8,000	1540	260	17.0	1940	580	30.0

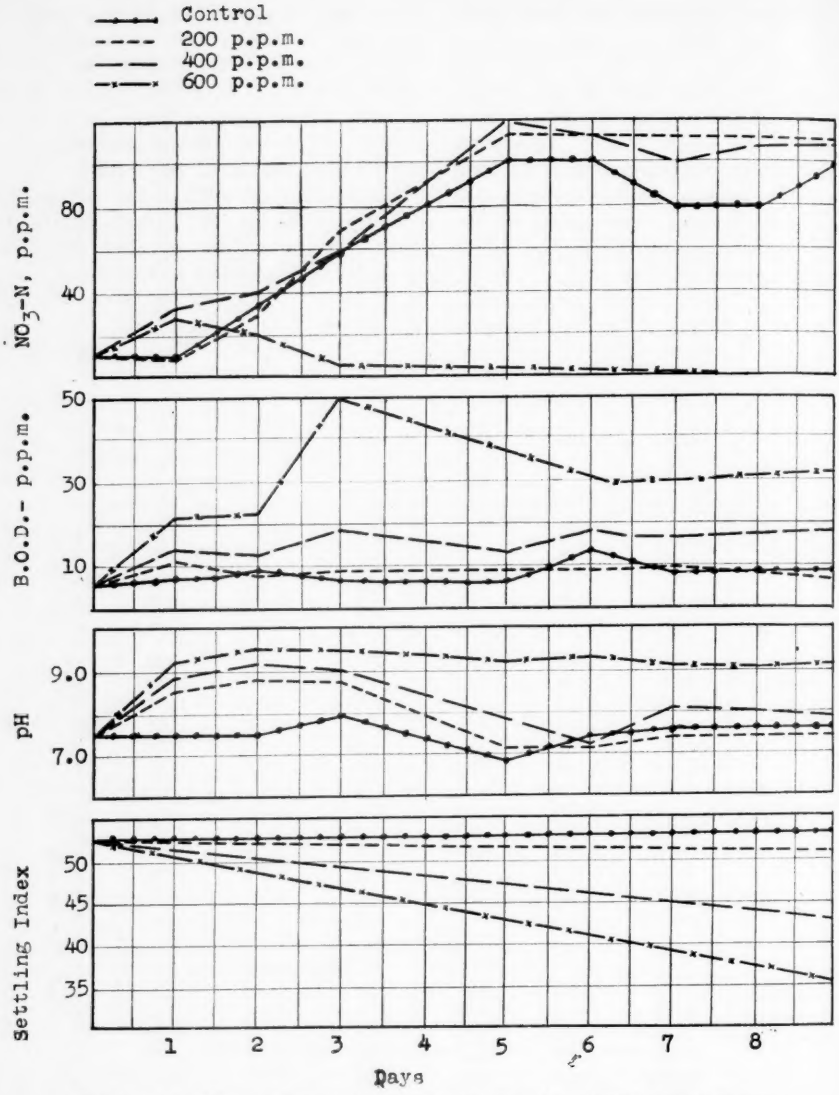

FIGURE 4.—Effect of ammonium carbonate on the activated sludge process.

the settled waste and from four to six times for the whole waste, for the same effect on nitrification.

The critical concentration for material reduction of biochemical oxidation efficiency of the process is somewhat higher than the concentration which impairs nitrification but, as would be expected, lies close to that concentration where nitrification is destroyed. This is demonstrated in Figures 1 to 3. From observations made during the course of the studies, the increased B.O.D. of the settled sludge liquor is due both to impairment of biological action and to disintegration of the activated sludge floc.

Not too surprisingly, the effect of

the wastes on the settling characteristics of the activated sludge floc (Figures 1 to 3) was to increase the density of the sludge. The degree of compactness of the settled sludge varied in more or less proportion to the amount of waste added. This effect applied to either whole or settled wastes, although generally the whole wastes produced the greatest sludge compactness. The cause of this increased sludge density appears to be tied in with precipitation of insoluble mineral constituents of the waste liquors, as illustrated by the increase of ash content of the activated sludge solids, shown in both Tables II and III.

The data would seem to show that the predominate factor in the wastes that affects the activated sludge process is the high alkalinity in the form of carbonates. An examination of Table III will show that impairment of nitrification began between pH 8.0 and 8.4 for the treated waste solutions, and was destroyed between pH 8.4 and 9.0. That there was some added toxicity factor due to the heavy metals of the wastes, however, is indicated by an inspection and comparison of the results of adding ammonium carbonate to the activated sludge under circumstances similar to those where the metal plating wastes were added. Definite impairment of nitrification with ammonium carbonate (Figure 4) did not occur with a pH less than 9.0. Destruction of nitrification required a pH of 9.5.

Part II—Sludge Digestion

Results

The observed effects of the wastes on the sludge digestion process are shown in Figures 5 and 6, which give cumulative daily gas production corresponding to increasing increments of added wastes. Tables IV and V give the total gas production of the units over the entire period of study (approximately 30 days), and the pH, solids, and ash in the sludge at the beginning and end of the digestion period. Table VI gives the extent and time required for recovery of the sludges after the waste additions were stopped.

In each, the whole waste addition (Figure 5) and the fractional waste addition without waste sludge—(Figure 6), the experiments started with 500

TABLE III.—Indicated Tolerance Limits of Activated Sludge Nitrification to Treated Metal Plating Wastes

Waste or Chemical Added	Nitrification Affected					Nitrification Destroyed					Controls		
	Waste, Wet Basis (p.p.m.)	Mg. Waste per Gm. Vol. Solids	Ave. pH	Ave. Suspended Solids (p.p.m.)	Ave. Ash (%)	Waste, Wet Basis (p.p.m.)	Mg. Waste per Gm. Vol. Solids	Ave. pH	Ave. Suspended Solids (p.p.m.)	Ave. Ash (%)	Ave. pH	Ave. Suspended Solids (p.p.m.)	Ave. Ash (%)
Whole Waste													
Carb. Soln.	2000	1000	8.2	2590	22.6	5000	2760	9.0	2540	25.3	7.6	2705	17.5
Zinc Pl. Soln.	3000	1260	8.2	2900	27.9	6000	2640	8.4	3060	31.6	7.5	3000	17.8
Copper Pl. Soln.	2000	1220	8.0	2100	23.1	4000	2400	8.6	2320	27.4	7.5	1985	17.6
Settled Waste													
Carb. Soln.	4000	2360	8.2	2700	23.1	6000	3470	8.5	2950	28.4	6.6	2305	12.5
Zinc Pl. Soln.	6000	3780	8.4	1870	19.0	9000	5420	8.7	1980	19.4	6.5	1785	11.8
Copper Pl. Soln.	4000	3000	8.4	1810	21.1	6000	4650	8.9	1780	22.2	6.8	1870	17.0
Waste Component													
$(NH_4)_2CO_3$	400–600	—	9.0	—	—	600	—	—	—	—	7.6	—	—

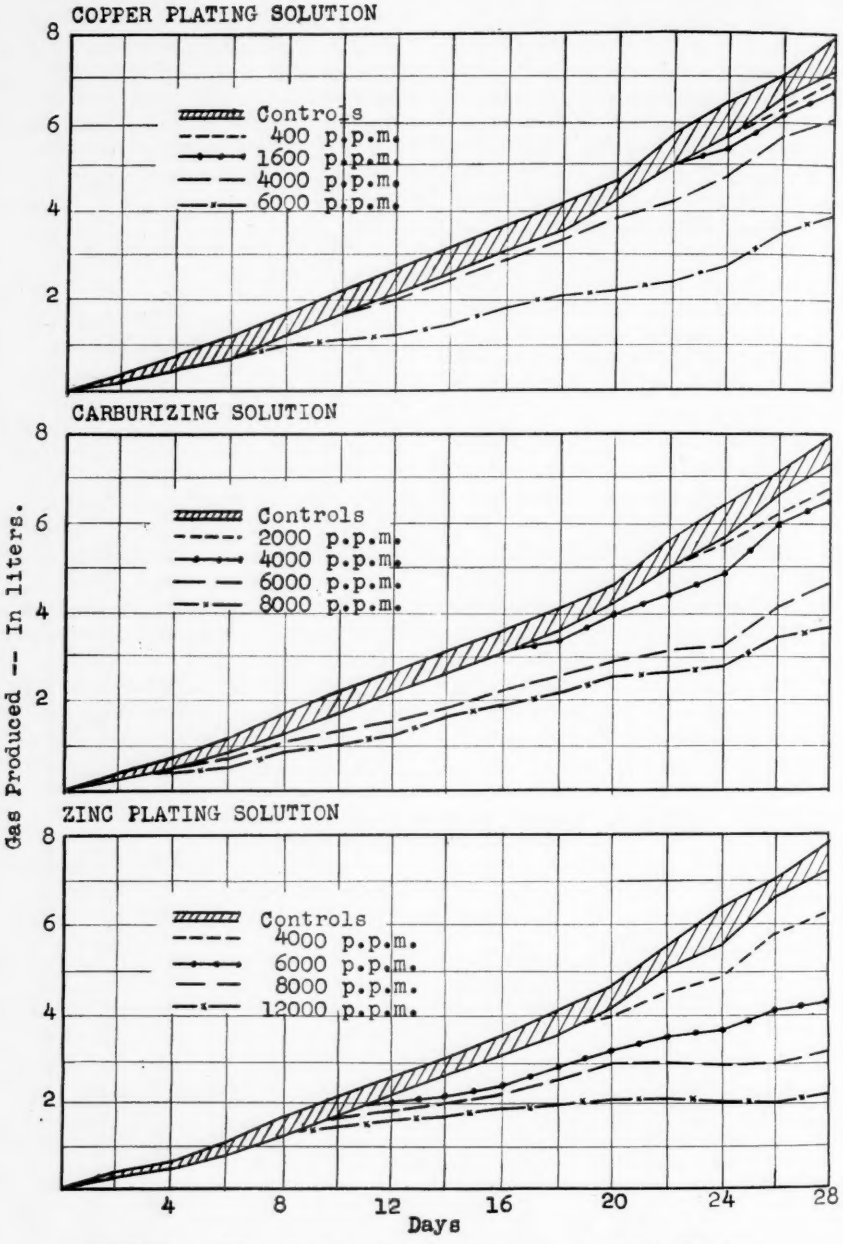

FIGURE 5.—Effect of whole electroplating wastes on sludge digestion.

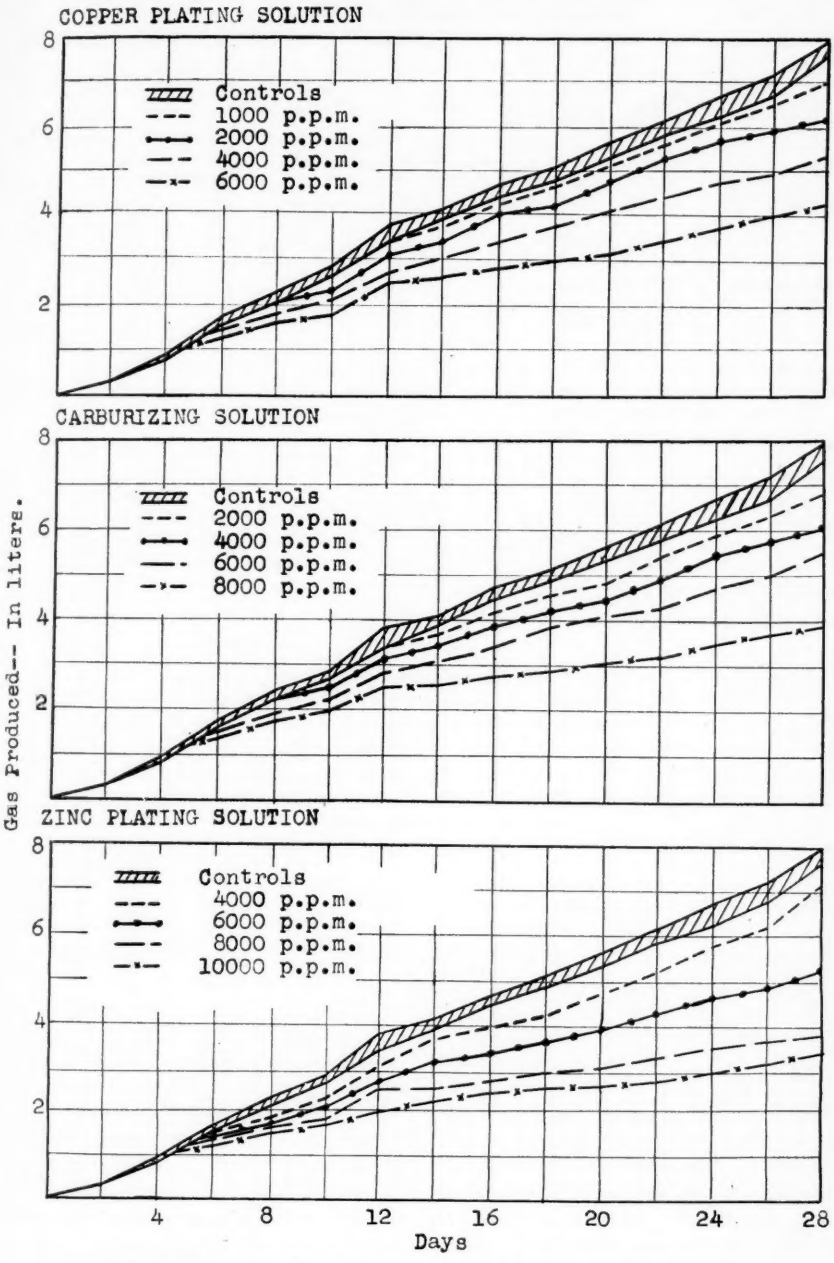

FIGURE 6.—Effect of settled electroplating wastes on sludge digestion.

TABLE IV.—Effects of Whole Wastes on Total Gas Production, Solids and pH of Digesting Sludge

Treated Waste	Waste Added (p.p.m.)	Total Gas Produced (ml.)	pH		Sludge			
					Solids (%)		Ash (%)	
			Begin.	End.	Begin.	End.	Begin.	End.
Control No. 1	0	7000	8.0	7.7	8.32	5.51	59.5	60.9
No. 2	0	7600	8.0	7.6	8.32	5.81	59.5	56.8
No. 3	0	8000	8.0	7.7	8.32	5.88	59.5	58.4
Carburizing Soln.	1,000	7500	8.0	7.75	8.32	5.98	59.5	63.0
	2,000	6800	8.0	7.9	8.32	7.41	59.5	64.8
	6,000	4600	8.0	8.0	8.32	8.12	59.5	70.5
	8,000	3700	8.0	8.15	8.32	9.0	59.5	72.9
Zinc Pl. Soln.	2,000	7200	8.0	7.75	8.32	6.80	59.5	65.1
	4,000	6300	8.0	7.85	8.32	7.51	59.5	65.5
	6,000	4250	8.0	8.0	8.32	8.20	59.5	65.0
	10,000	2200	8.0	8.4	8.32	8.75	59.5	76.2
Copper Pl. Soln.	400	7000	8.0	7.9	8.32	5.95	59.5	56.0
	1,600	6700	8.0	8.1	8.32	6.59	59.5	59.2
	4,000	6000	8.0	8.25	8.32	7.70	59.5	68.0
	6,000	4000	8.0	8.45	8.32	8.42	59.5	71.8

TABLE V.—Effects of Settled Wastes on Total Gas Production, Solids and pH of Digesting Sludge

Treated Waste	Waste Added (p.p.m.)	Total Gas Produced (ml.)	pH		Sludge			
					Solids (%)		Ash (%)	
			Begin.	End.	Begin.	End.	Begin.	End.
Control No. 1	0	8000	7.5	7.4	10.4	5.15	62.9	54.9
No. 2	0	7600	7.5	7.4	10.4	5.37	62.9	58.0
No. 3	0	7500	7.5	7.4	10.4	5.00	62.9	56.2
Carburizing Soln.	1,000	7800	7.5	—	10.4	6.09	62.9	53.5
	2,000	6800	7.5	—	10.4	?	62.9	?
	4,000	6000	7.5	—	10.4	6.50	62.9	56.2
	6,000	5500	7.5	—	10.4	7.48	62.9	58.8
	8,000	3950	7.5	7.4	10.4	7.55	62.9	61.9
Zinc Pl. Soln.	2,000	7600	7.5	—	10.4	5.98	62.9	55.8
	4,000	7300	7.5	—	10.4	6.48	62.9	57.6
	6,000	5250	7.5	—	10.4	6.98	62.9	63.1
	8,000	3800	7.5	—	10.4	7.29	62.9	64.0
	10,000	3400	7.5	7.4	10.4	7.20	62.9	66.8
Copper Pl. Soln.	400	7400	7.5	—	10.4	5.82	62.9	52.5
	2,000	6200	7.5	—	10.4	6.21	62.9	55.9
	4,000	5350	7.5	—	10.4	6.70	62.9	60.8
	6,000	4250	7.5	7.8	10.4	7.40	62.9	62.0

TABLE VI.—Daily Gas Production in Ml. from Digesting Sludge During Recovery Period

Waste	Last Day of Exp. Run	Days of Recovery						
		2nd	5th	8th	9th	13th	17th	24th
Control No. 1	205	310	250	240	215	330	440	300
No. 2	225	295	235	230	235	320	440	300
No. 3	250	245	250	220	215	330	410	280
Copper Plating								
400 p.p.m.	200	245	235	220	—	—	—	—
2,000 p.p.m.	140	135	255	225	—	—	—	—
6,000 p.p.m.	100	190	255	225	—	—	—	—
Carburizing Salt Bath								
1,000 p.p.m.	285	315	265	210	—	—	—	—
2,000 p.p.m.	240	285	260	200	—	—	—	—
6,000 p.p.m.	200	105	255	245	—	—	—	—
8,000 p.p.m.	185	145	230	245	—	—	—	—
10,000 p.p.m.	15	0	180	240	—	—	—	—
Zinc Plating								
2,000 p.p.m.	230	225	265	220	—	—	—	—
6,000 p.p.m.	180	165	265	250	—	—	—	—
8,000 p.p.m.	170	120	255	250	—	—	—	—
10,000 p.p.m.	65	45	55	95	85	335	485	415
12,000 p.p.m.	0	20	75	75	85	220	425	425

grams of active digested sludge in each unit. The analysis of this sludge is given in the Tables IV and V in the form of the control at the beginning. To each of these units 15 ml. of raw, finely screened sewage sludge was added daily. The average solids content of this fresh sludge was 4.5 per cent with an ash content of 28 per cent. Daily additions on the beginning sludge volumes were thus in the rates of 0.448 grams of raw sewage volatile matter to 41.5 grams of digested sludge or 1.2 per cent volatile to digested sludge on a dry weight basis. In Figure 6 the daily additions of fresh sewage volatile matter to digested sludge, dry weight basis was 1.1 per cent. Amounts of treated cyanide wastes added are given in terms of parts per million of liquid wastes on basis of wet digested sludge volume.

Discussion of Results

The data in Table IV and Figure 5, where the whole waste including sludge was added, show that if in sufficiently high concentrations all treated wastes affect the digestion of sludge. The toxic effect varies from a slight retardation to a definite toxic action which entirely stops digestion, depending on the amount. Relatively, the copper plating waste is by far the most toxic of the three.

For approximately equal reduction in total gas production over the entire digestion period, two and one-half times as much carburizing salt bath solution and five times as much zinc plating solution were tolerated as copper plating solution.

All wastes gave increases in pH of the digesting sludge corresponding to the amount added. The specific factor in these wastes responsible for the depressant or toxic action are difficult to isolate. However, the combination of the toxic metal ions present in each, and the increase in pH of the sludge caused by the wastes are both well known influences in this respect. It is

also noticeable from the data that neither the sludge concentration nor ash are adversely affected by the wastes. Increasing quantities of all wastes were accompanied by higher percentages of solids and ash in the sludge. This is, of course, assumed due to the inorganic solids added and sludges treated with the highest concentrations of zinc plating solutions (10,000 to 12,000 p.p.m.) occurred within 5 days.

The comparison between the tolerance levels of the alkaline-chlorine and polysulfide treated metal plating solutions is shown by the following:

Comparison of Tolerance Levels of Alkali-Chlorine and Polysulfide Treated Wastes on Sludge Digestion

Treated Waste Solutions	Gas Production					
	Unaffected at (p.p.m.)			Affected at (p.p.m.)		
	Polysulfide*	Alkali-Chlorine		Polysulfide	Alkali-Chlorine	
		Whole	Settled		Whole	Settled
Carburizing	1200	1000	1000	1500	2000	2000
Zinc Plating	600	2000	2000	900	4000	4000
Copper Plating	200	400	400	300	1000	1000

* Waste solution (p.p.m.) added daily to digester contents.

possibly precipitated from the waste solution.

An examination of the data showing results from the addition of the wastes from which the inorganic sludge had been separated (Tables V and Figure 6) shows similar general characteristics of depression of gas production and toxicity, the major difference from the whole wastes appearing in less decrease in moisture of the sludge, less increase in ash and less increase in pH with increasing additions of the wastes. It appears from this that the soluble materials in the wastes in the form of the residual metal ions are principally responsible for the depressant action.

Of specific interest is the evidence shown in Table VI that with the exception of the highest treated zinc plating units, none of the wastes showed any permanent effects on the digesting sludge. With these two exceptions, daily production of gas from all waste treated sludges had attained a rate falling within that shown by the controls within a maximum of 8 days. Recovery by all except those

The difference in toxicity of these two different pretreatments of the wastes in favor of the alkali-chlorine method is not quite so pronounced in digestion of sludge as in the activated sludge treatment method. However, with the exception of the carburizing solutions, the lesser toxicity of the alkali-chlorine treated wastes is material.

Summary

With increased industrialization of the country-at-large over the past years, and particularly of the smaller communities since the beginning of the last war, it has become a question of increasing importance of what amounts of industrial wastes, pretreated or otherwise, can be introduced into the sewage entering the sewage treatment plant before serious impairment of the process occurs. Of further interest are the probable effects and the permanency of impairment of the sewage treatment processes.

The above data, viewed in this light, would indicate that in regard to the

aerobic sewage treatment methods, the alkali-chlorine treated wastes are toxic, if concentrations are high enough, but a relatively high concentration is tolerable in the sewage before the efficiency of the sewage treatment process is seriously impaired. Taking for example 2,000 p.p.m. of alkali-chlorine treated zinc plating whole waste, this would mean that 16,000 lb. of treated waste could be tolerated by the sewage plant per million gallons of sewage flow, if held in storage tanks and distributed over a 24-hour period. This is equivalent to the treated waste from an 1,800- to 2,000-gal. concentrated electroplating bath dump per day per million gallons of sewage flow which is extremely out of proportion to probable occurrence.

These data would also indicate that treated electroplating rinse wastes, even in relatively high concentrations, would have no effect on the activated sludge process. Practical circumstances are usually such that this waste is most desirably discharged to the public sewer system. It appears, therefore, that with proper treatment of either the concentrated electroplating wastes or rinse wastes, and reasonable holding and distributing devices at the industrial plant, the disposal of alkali-chlorine treated electroplating wastes in a sewer system served by a sewage treatment plant using oxidation devices is practical, except where the ratio of wastes to receiving sewage is of abnormal proportions.

The digestion units of sewage plants receiving these wastes in mixture with domestic sewage will be even less affected, due to the relatively small proportions of the waste liquid reaching the digesters.

Since these conclusions are drawn from the whole treated waste it is evident that proper settling of the treated metal plating wastes at the site of waste treatment would make the disposal of the wastes to the sewer system even less deleterious.

Acknowledgment

The work reported herein was financed by the Electro-Chemicals Department of E. I. duPont de Nemours & Co., Niagara Falls, New York. Samples of the waste solutions and many of the waste analyses were also obtained through the cooperation of the same organization.

The valuable help of Pauline Wilson, laboratory technician, in the Department of Environmental Health, School of Public Health, University of Michigan, is also gratefully acknowledged.

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THE TOXICITY TO WARM-WATER FISHES OF CERTAIN CYANIDE PLATING AND CARBURIZING SALTS BEFORE AND AFTER TREATMENT BY THE ALKALI-CHLORINATION METHOD [1]

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The safe disposal of wastes containing cyanide salts has always offered many difficulties to the operators of electroplating plants because of the toxic nature of these substances to aquatic life, and the necessity of using large amounts of water for washing purposes. When cyanide wastes are discharged directly into a stream large volumes of dilution water are required to render the effluent innocuous, and in many instances the water supplies essential for such dilutions are limited. The plant therefore either must resort to some other method of disposal or must run the risk of contaminating public waters. Although several methods have been developed in the past to eliminate or reduce the hazard of cyanide disposal, they have not been universally accepted by the plating industry because of the high cost of equipment involved or the amount of technical help required to follow such procedures.

Since many of the plating plants of today are small establishments, it is considered highly desirable that a method be developed which can be used satisfactorily in both small and large plants. The alkali-chlorination method appears to be applicable to such operations. It consists of treatment of plating wastes with chlorine in the presence of an alkaline medium, breaking down the CN radical through a series of chemical reactions (1), and destroying the characteristic toxic ion. Naturally, following the development of this method it was necessary to determine the extent of reduction in toxicity. Since many plating wastes eventually reach streams containing fish populations, it was believed that fish should be used as experimental animals in a series of tests aimed at establishing an *index of toxicity* which would facilitate direct comparisons of the toxicity of untreated and treated wastes. A study of this nature was undertaken during the winter and spring of 1946 and 1947 by the Institute for E. I. Du Pont de Nemours & Company.

Materials and Methods

The chemicals used in these tests, supplied by Du Pont, consisted of untreated and treated copper plating salts, zinc plating salts, and carburizing salts solutions. These solutions were prepared specifically for the present study, at higher than normal concentrations. The analyses covering these solutions, as supplied by Du Pont, are quoted as follows:

"A. *Du Pont High Speed Copper Plating Salts*

Du Pont High Speed Copper Plating Salts were mixed with 9 gallons of water in an amount sufficient to obtain a solution with a total cyanide content of 5 per cent expressed as NaCN.

1. Untreated—Two 1-gallon portions of this solution were set aside (NaCN content 5.0 per cent; pH over 13).

[1] Contribution from the Michigan Institute for Fisheries Research.

[2] Now with Ozark Fisheries, Inc., Stoutland, Mo.

2. Chlorinated—The remainder of the solution (approximately 7 gallons) was treated with 20 pounds of NaOH and 16 pounds of Cl_2 (4.9 pounds Cl_2 per pound NaCN). Properties of the final liquor were: specific gravity, 1.32 (25)/(4); pH, 11.8; NaCNO, none detected; available Cl_2, none detected; NaCN, less than 1 p.p.m.; Cu in filtrate, 1 p.p.m.; and Cu in sludge 12.1 per cent (dry basis).

"B. *Du Pont 'Durobrite' Zinc Plating Salts*

A sufficient amount of Du Pont "Durobrite" Zinc Plating Salts was mixed with 9 gallons of water to obtain a solution with a total cyanide content of 5 per cent expressed as NaCN.

1. Untreated—Two 1-gallon portions of this solution were set aside (NaCN content 5.0 per cent; pH over 13).
2. Chlorinated—The remainder of the solutions (approximately 7 gallons) was treated with 9 pounds of NaOH and 10 pounds of Cl_2 (3.1 pounds Cl_2 per pound NaCN). Properties of the final liquor were: specific gravity, 1.25 (25)/(4); pH, 11.0; available Cl_2, 0.02 per cent; NaCNO, 0.13 per cent; NaCN, less than 1 p.p.m.; zinc in filtrate, 5 p.p.m.; and zinc in sludge, 60.2 per cent (dry basis).

"C. *Du Pont Carburizing Salts*

A sufficient amount of a mixture of one part Du Pont Carburizing Salt to two parts Du Pont Heat Treating Salt No. 6 (the recommended starting mixture for the Du Pont Carburizing Salt Bath) was dissolved in 9 gallons of water to obtain a solution with a total cyanide content of 2.5 per cent expressed as NaCN.

1. Untreated—Two 1-gallon portions of this solution were set aside (NaCN content, 2.5 per cent).
2. Chlorinated—The remainder of the solution (approximately 7 gallons) was treated with 9 pounds of NaOH and 6.5 pounds of Cl_2 (3.6 pounds Cl_2 per pound NaCN). Properties of the final liquor were: specific gravity, 1.29 (25)/(4); pH, 11.6; available Cl_2, 0.037 per cent; NaCNO, 0.5 per cent; and NaCN, less than 1 p.p.m."

Test fish consisted of the bluegill (*Lepomis macrochirus*) and the brown bullhead (*Ameiurus nebulosus*). The bluegills, 1½ to 2½ in. in length, were secured from Deep Lake, Oakland County, Mich., and from the Wolf Lake State Fish Hatchery in Van Buren County, Mich. The bullheads, which ranged in length from 2 to 3½ in., were obtained from Portage Creek, Jackson County, Mich., and from the Comstock Park State Fish Hatchery in Kent County, Mich. Care was taken in the collection of these fish to select only healthy individuals.

The water used for retaining the stock supply of fish, for the dilution of the plating materials, and for other purposes directly concerned with the study, was secured from Fleming Creek, Washtenaw County, Mich. This water was considered to be representative of normal stream waters in which a moderate population of fishes could be sustained successfully. The total hardness (M.O. alkalinity) was 188 p.p.m. The pH averaged about 8.4. No free carbon dioxide or other noxious gases were present.

The test equipment consisted of 1-gal. glass jars, each equipped with a cover and an air release. All contacts with the plating elements were made with either glass or non-corrosive fixtures. The solution temperature was approximately that of the laboratory, 72° F.

The test procedure employed to determine the relative toxicity of the plating solutions to fishes consisted of preparing a series of stock solutions representing a wide range of concentration for each of the products, and exposing from three to five fishes to each concentration. The test jars were supplied with 3,000 ml. of stock solution, and the fish were retained in a given solution for a period not exceeding 96 consecutive hours. At frequent intervals within this period the condition of the fish was noted and if any dead

were present they were immediately removed to prevent possible contamination. During the entire study, control jars were in constant operation and a periodic check was made of the reserve stock of fish being retained in a holding tank within the laboratory. The toxicity of the plating baths was measured in terms of the reaction of fish exposed to varying concentrations. The degree of toxicity was evaluated in terms of the "consistent tolerance limit," an expression denoting the highest concentration at which all of the test animals survived a 96-hr. exposure.

Procedure

Four groups of experiments involving 214 individual tests were undertaken during the study. The group tests consisted of determining the relative toxicity of (1) each of the three untreated and treated wastes, (2) the supernatant of the treated waste, (3) the sludge of the treated waste, and (4) the sludge of the treated waste after undergoing slight acidification.

The three raw plating solutions were found to possess high toxic values; the consistent tolerance limit (in terms of the actual residual cyanide present) was 0.4 p.p.m. for the bluegill and 0.5 p.p.m. for the bullhead, for both the copper and zinc plating solutions. The toxicity of the carburizing salts solution was found to be somewhat greater, the nonlethal limit being established at 0.25 and 0.375 p.p.m., respectively, for the bluegill and the bullhead.

Results of the toxicity test are best expressed in degrees of dilution of the basic plating baths (Table I). On this basis the values are expressed in higher units than when expressed in terms of cyanide content. The tolerance levels for the bluegill were 8, 8, and 10 p.p.m. in the copper, zinc, and carburizing baths, respectively. The consistent tolerance levels for the bullhead were 10, 10, and 15 p.p.m., respectively.

Throughout the tests, the fish (both bluegills and bullheads) either succumbed within a few hours or less, or (in most instances) survived the 96-hr. exposure. This result suggested that the test solutions lost some of their toxicity during the time interval of the testing. Since a constant stream of air was being forced through the test solutions, it is possible that through hydrolysis the active toxic substances were quickly broken down.

A very significant change in the degree of tolerance of the fishes was noted when they were subjected to the plating solutions which had undergone the alkali-chlorination treatment. For these tests the consistent tolerance limits are expressed in terms of the original cyanide value before treatment. For the bluegill the limits were fixed at 250, 350, and 175 p.p.m. for the copper, zinc, and carburizing solutions, respectively (Table II). For the bullhead the non-lethal limits established for copper, zinc, and carburizing solutions were 300, 400, and 225 p.p.m. These toxicity values become much more significant when expressed in terms of dilution of basic plating baths (stock material). The consistent tolerance limits of the bluegill for the three products—copper, zinc, and carburizing solutions—were 5,000, 7,000, and 7,000 p.p.m., respectively; for the bullhead the values, in the above order were 6,000, 8,000, and 9,000 p.p.m.

Comparison of the data presented in Tables I and II shows that the toxic values for each of the products were changed materially by treatment. From a low of 8 p.p.m. of basic stock of copper plating solution, representing the highest non-lethal concentration to bluegills, the value was increased to 5,000 p.p.m.; by treatment for the zinc solution from 8 to 7,000 p.p.m.; and for the carburizing solution from 10 to 7,000 p.p.m. Similarly, for the bullhead, the index of toxicity of the copper plating solution changed from a low of 10 to 6,000 p.p.m. following

TABLE I.—The Toxicity of Untreated Copper Plating, Zinc Plating and Carburizing Salts Solutions to Bluegills and Bullheads

Concentration of Basic Plating Baths (p.p.m.)	Materials Used in Test											
	Copper Plating Salts			Zinc Plating Salts			Carburizing Salts					
	Residual NaCN Content (p.p.m.)	Species and Survival Time[1]		Residual NaCN Content (p.p.m.)	Species and Survival Time[1]			Residual NaCN Content (p.p.m.)	Species and Survival Time[1]			
		Bluegill	Bullhead		Bluegill	Bullhead			Bluegill		Bullhead	
		Survival Time	Survival Time		Survival Time	Survival Time			Survival Time		Survival Time	
2,000	100.00	No test	No test	100.00	5 to 7 min.	5 to 8 min.		50.000	No test		No test	
1,000	50.00	9 to 12 min.	7 to 12 min.	50.00	5 to 7 min.	No test		25.000	3 to 4 min.		2 to 6 min.	
500	25.00	6 to 14 min.	No test	25.00	No test	7 to 12 min.		12.500	6 to 12 min.		No test	
200	10.00	No test	16 to 38 min.	10.00	8 to 12 min.	No test		5.000	No test		45 to 87 min.	
100	5.00	11 to 24 min.	3 to 5 hr.	5.00	No test	93 to 187 min.		2.500	6 to 15 min.		88 to 161 min.	
50	2.50	No test	6 to 13 hr.	2.50	No test	96 to 139 min.		1.250	No test		No test	
40	2.00	No test	No test	2.00	22 to 40 min.	No test		1.000	No test		No test	
20	1.00	30 to 83 min.	31 to 96 hr.	1.00	51 to 120 min.	3 to 5 hr.		0.500	28 to 50 min.		31 to 96 hr.	
15	0.75	No test	No test	0.75	No test	No test		0.375	No test		96+ hr.	
12	0.60	60 to 142 min.	No test	0.60	3 to 4 hr.	38 to 96 hr.		0.300	No test		No test	
10	0.50	3 to 3.5 hr.	96+ hr.	0.50	No test	96+ hr.		0.250	96+ hr.		96+ hr.	
8	0.40	96+ hr.	96+ hr.	0.40	96+ hr.	No test		0.200	No test		No test	
6	0.30	96+ hr.	No test	0.30	96+ hr.	No test		0.150	96+ hr.		No test	
5	0.25	No test	96+ hr.	0.25	No test	96+ hr.		0.125	No test		96+ hr.	
4	0.20	No test	No test	0.20	96+ hr.	No test		0.100	96+ hr.		No test	
2	0.10	96+ hr.	No test	0.10	No test	No test		0.050	96+ hr.		No test	
1	0.05	96+ hr.	No test	0.05	No test	No test		0.025	96+ hr.		No test	
0	0.00	96+ hr.	96+ hr.	0.00	96+ hr.	96+ hr.		0.000	96+ hr.		96+ hr.	

[1] Five fish used in each test.

TABLE II.—The Toxicity of Treated Copper Plating, Zinc Plating and Carburizing Salts Solutions to Bluegills and Bullheads

Concentration of Basic Plating Baths (p.p.m.)	Materials Used in Test								
	Copper Plating Salts			Zinc Plating Salts			Carburizing Salts		
	Original NaCN Content (p.p.m.)	Species and Survival Time[1]		Original NaCN Content (p.p.m.)	Species and Survival Time[1]		Original NaCN Content (p.p.m.)	Species and Survival Time[1]	
		Bluegill	Bullhead		Bluegill	Bullhead		Bluegill	Bullhead
		Survival Time	Survival Time		Survival Time	Survival Time		Survival Time	Survival Time
80,000	4,000	7 to 8 min.	5 to 7 min.	4,000	5 to 6 min.	5 to 20 min.	2,000	6 to 8 min.	7 to 10 min.
60,000	3,000	4 to 8 min.	6 to 7 min.	3,000	8 to 9 min.	7 to 17 min.	1,500	5 to 7 min.	9 to 10 min.
40,000	2,000	5 to 8 min.	8 to 12 min.	2,000	9 to 11 min.	20 to 28 min.	1,000	7 to 9 min.	18 to 20 min.
20,000	1,000	9 to 10 min.	11 to 26 min.	1,000	10 to 15 min.	39 to 47 min.	500	32 to 51 min.	23 to 29 min.
15,000	750	16 to 18 min.	15 to 48 min.	750	15 to 23 min.	45 to 89 min	350	24 to 63 min.	49 to 57 min.
10,000	500	160 to 208 min.	19 to 56 min.	500	15 to 96 hr.	68 to 138 min.	250	13 to 17 hr.	16 to 96 hr.
9,000	450	No test	No test	450	16 to 96 hr.	4 to 67 hr.	225	30 to 96 hr.	96+ hr.
8,000	400	3 to 96 hr.	11 to 18 hr.	400	28 to 96 hr.	96+ hr.	200	44 to 96 hr.	96+ hr.
7,000	350	5 to 96 hr.	29 to 96 hr.	350	96+ hr.	96+ hr.	175	96+ hr.	96+ hr.
6,000	300	22 to 96 hr.	96+ hr.	300	96+ hr.	96+ hr.	150	96+ hr.	96+ hr.
5,800	290	31 to 96 hr.	96+ hr.	290	No test	No test	145	96+ hr.	No test
5,400	270	44 to 96 hr.	96+ hr.	270	No test	No test	135	96+ hr.	No test
5,000	250	96+ hr.	96+ hr.	250	96+ hr.	96+ hr.	125	96+ hr.	96+ hr.
4,000	200	96+ hr.	96+ hr.	200	No test	No test	100	96+ hr.	96+ hr.
000	000	96+ hr.	96+ hr.	000	No test	No test	000	96+ hr.	96+ hr.

[1] Five fish used in each concentration tested.

treatment; for the zinc, from 10 to 8,000; and for the carburizing solution, from 15 to 9,000 p.p.m.

It can also be noted that although a significant reduction in toxicity has been expressed in values for the treated products, the reduction does not come up to expectations on the basis of the original analyses, which indicated that all or at least most of the detectable cyanide had been destroyed.

In order to achieve a more thorough understanding of the toxic nature of the treated materials, toxicity tests were run on the basic component parts —supernatant and sludge. It was found that the supernatant of each of the three products was more toxic than the basic stock. The consistent tolerance limit established for the bluegill in terms of p.p.m. was 3,500 for the copper plating solution, 4,000 for the zinc plate, and 4,000 for the carburizing solution. The values of tolerance established for the bullhead were in general somewhat lower (Table III)—3,000 p.p.m. in the copper plating solution, 4,000 in the zinc, and 3,500 in the carburizing solution.

From the finding that the supernatants possessed higher toxic values than the composite solutions, it was deduced that the sludge would be less toxic. The sludge constituted from 15 to 20 per cent of the total volume, and should have had some important role in the toxicity, one way or the other. Samples of sludge were removed from each of the three solutions by filtration, thoroughly washed to assure the entire removal of the supernatant, and employed in a series of toleration tests. Results presented in Table IV, in comparison with the figures in Table III show that the sludge was appreciably less toxic than the supernatant. Even though only wide-range toleration tests were performed, the consistent tolerance limit was established at much higher concentrations for sludge than for supernatant. Bluegills were found to tolerate con-

TABLE III.—Relative Tolerance of Bluegills and Bullheads to the Supernatant of Treated Copper, Zinc and Carburizing Salts Solutions

Concentration of Supernatant Liquor (p.p.m.)	Materials Used in Tests					
	Copper Plating Salts		Zinc Plating Salts		Carburizing Salts	
	Species and Survival Time[1]		Species and Survival Time[1]		Species and Survival Time[1]	
	Bluegill	Bullhead	Bluegill	Bullhead	Bluegill	Bullhead
	Survival Time	Survival Time	Survival Time	Survival Time	Survival Time	Survival Time
40,000	8 to 12 min.	No test	No test	No test	5 to 12 min.	No test
20,000	16 to 22 min.	6 to 14 min.	28 to 47 min.	28 to 47 min.	24 to 26 min.	10 to 20 min.
15,000	No test	No test	No test	No test	38 to 62 min.	No test
12,000	No test	No test	No test	No test	1.5 to 16 hr.	No test
10,000	2 to 16 hr.	42 to 95 min.	2 to 18 hr.	2 to 18 hr.	No test	2 to 4.5 hr.
9,000	No test	No test	No test	No test	1 to 22.5 hr.	No test
8,000	No test	No test	No test	No test	No test	No test
7,000	12 to 16 hr.	No test	No test	No test	12 to 16 hr.	No test
6,000	No test	No test	No test	No test	27 to 96 hr.	No test
5,000	29 to 57 hr.	No test	34 to 96 hr.	34 to 96 hr.	36 to 96 hr.	No test
4,000	36 to 96 hr.	28 to 51 hr.	96+ hr.	96+ hr.	96+ hr.	4 to 18 hr.
3,500	96+ hr.	42 to 96 hr.	No test	No test	No test	96+ hr.
3,000	96+ hr.	96+ hr.	96+ hr.	96+ hr.	96+ hr.	96+ hr.
000	96+ hr.	96+ hr.	96+ hr.	96+ hr.	96+ hr.	96+ hr.

[1] Five fish used in each concentration listed.

TABLE IV.—The Toxicity to Bluegills and Bullheads of Sludges Derived from Treated Copper Plating, Zinc Plating and Carburizing Salts Solutions, Together with Comparison of the Toxicity of Alkaline and Acidified Sludges

Concentration of Sludge (p.p.m.)	Materials Used in Tests								
	Alkaline Sludge Solution, pH 11.0 to 11.6						Acid Sludge Solution, pH 6.2 to 6.6		
	Copper Plating Salts		Zinc Plating Salts		Carburizing Salts		Copper Plating Salts	Zinc Plating Salts	Carburizing Salts
	Species and Survival Time[1]		Species and Survival Time[1]		Species and Survival Time[1]		Species and Survival Time[1]		
	Bluegill	Bullhead	Bluegill	Bullhead	Bluegill	Bullhead	Bluegill	Bluegill	Bluegill
	Survival Time	Survival Time	Survival Time	Survival Time	Survival Time	Survival Time	Survival Time	Survival Time	Survival Time
80,000	6 to 13 min.	96+ hr.	21 to 48 min.	96+ hr.	7 to 18 min.	96+ hr.	No test	No test	No test
60,000	No test	No test	16 to 96 hr.	No test	No test	No test	No test	No test	No test
40,000	11 to 24 min.	96+ hr.	96+ hr.	96+ hr.	3 to 96 hr.	96+ hr.	No test	1.5 to 2 hr.	No test
20,000	96+ hr.	96+ hr.	96+ hr.	96+ hr.	96+ hr.	96+ hr.	16 to 96 hr.	3 to 65 hr.	40 to 90 min.
10,000	96+ hr.	96+ hr.	96+ hr.	96+ hr.	96+ hr.	96+ hr.	96+ hr.	No test	96+ hr.
8,000	No test	No test	No test	No test	No test	No test	No test	96+ hr.	No test
7,000	96+ hr.	No test	No test	No test	96+ hr.	No test	No test	No test	No test
6,000	No test	No test	No test	No test	96+ hr.	No test	No test	96+ hr.	96+ hr.
4,000	96+ hr.	No test	No test	No test	No test	No test	No test	No test	No test
000	96+ hr.	96+ hr.	96+ hr.	96+ hr.	96+ hr.	96+ hr.	96+ hr.	96+ hr.	96+ hr.

[1] Three fish used in each concentration tested.

centrations ranging somewhere between 20,000 and 40,000 p.p.m. for the three products, and the bullheads in all cases in excess of 80,000 p.p.m.

Further examination was made of the toxic nature of the sludge after treatment with an acid buffer. Buffering made it possible to determine whether or not an increase in toxicity would result from ionization of the sludge. Techniques similar to those practiced in the above experiment were employed in sludge separation: the sludge was removed by filtration, carefully washed several times and then mixed into a hydrochloric acid solution and allowed to stand for 20 hours before use. The pH was adjusted at 6.2 for the copper plating solution, 6.4 for the zinc, and 6.6 for the carburizing salts solution. Only one species of fish (bluegill) was employed in these tests. The results (Table IV) indicate that the sludge for all three products became more toxic when buffered with an acid. The consistent tolerance limits were somewhere between 8,000 and 20,000 p.p.m. as compared with 20,000 to 40,000 values, the range of toleration for the species prior to acidification.

Discussion and Summary

Treatment of three electroplating wastes by the alkali-chlorination technique resulted in an appreciable reduction in toxicity. The treated copper plating solution was found to be 625 times less toxic to bluegills and 600 times less toxic to bullheads than was a homogenous part of the untreated product; treatment of the zinc plating solution resulted in a reduction in toxicity of 875 and 800 times for the bluegill and bullhead, respectively; and for the carburizing salts solution, the reduction was calculated at 700 and 600 times for the two species (Figure 1). By presenting the collective data from the study in another form, i.e., in relation to the ratio of the dilution water used, the economic value can be easily illustrated. For the untreated wastes, namely copper plating and zinc plating, the dilution water necessary to attain the highest non-lethal concentration approximated a ratio of 125,000 parts of water to 1 part of the test product. Following treatment, however, the ratio between dilution water and the waste was considerably reduced, amounting to only 200 to 1 for the copper plating and 143 to 1 for the zinc plating solution. For the carburizing salts, which formerly required a 100,000 to 1 dilution, the figure was altered to a 143 to 1 ratio.

Referring to the analyses of the untreated and treated materials, presented under "Materials and Methods," it is difficult to explain why in this study even lower values of toxicity were not obtained for the treated products, since the analyses indicated that the remaining residual cyanide at no time exceeded 1 p.p.m. It is believed that other chemicals, either singly, collectively, or by group action, contribute a major portion of the remaining toxicity. For example, sodium cyanate (NaCNO) is present in lethal concentrations in two of the three salts solutions, namely: the zinc plating and carburizing salts. Through experimentation the writer roughly established the maximum tolerance limit for the creek chub (*Semotilus a. atromaculatus*), a hardy fish, to sodium cyanate at 75 p.p.m. Assuming that the bluegill and bullhead are comparable to the creek chub in tolerance, it can be demonstrated that a moderate degree of the toxicity in the treated products can be accounted for in this manner. It can be noted in Table II under the column headed "zinc plating salts" that the minimum concentrations which produced lethal effects to the bluegill and bullhead were established at 7,000 and 8,000 p.p.m., respectively, of basic stock. These concentrations, according to the analyses supplied, would contain a residual NaCNO content of approximately 9.1

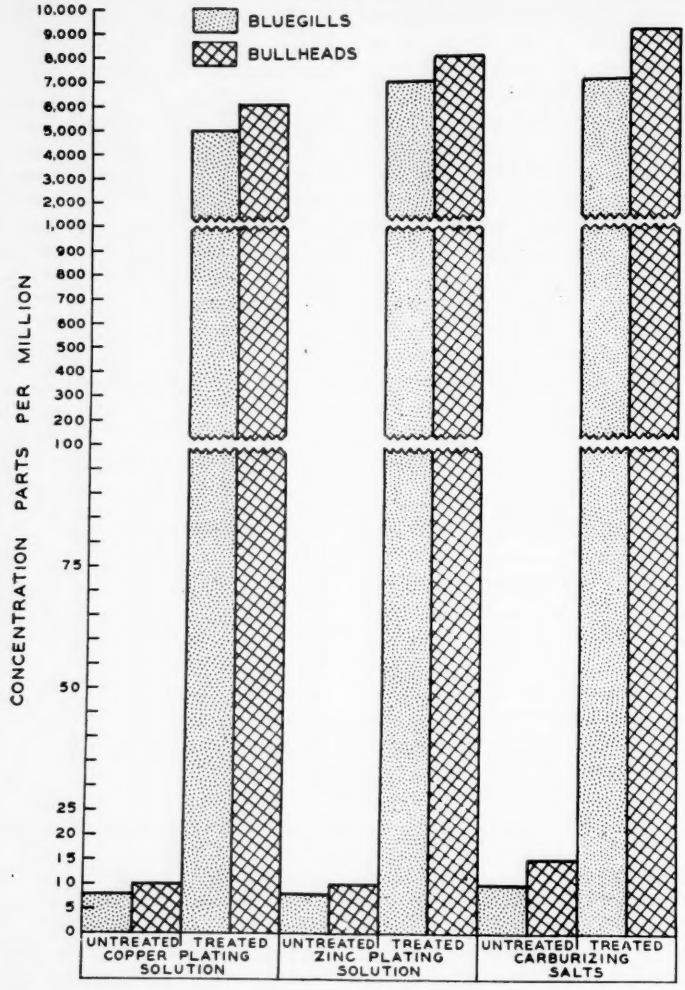

FIGURE 1.—Chart showing the tolerance of bluegills and bullheads to various concentrations of treated and untreated electroplating and carburizing wastes.

and 10.4 p.p.m., thus providing a substantial proportion of the toxic elements present. The NaCNO values in the carburizing bath were even higher; at a minimum lethal concentration of 7,000 p.p.m. for the bluegill and 9,000 p.p.m. for the bullhead, the NaCNO content would be 35 and 45 p.p.m.

The presence of chloride (not included in the analyses supplied by the Du Pont Company) may be a contributing factor. Sodium chloride (NaCl) in a concentration of 10,000 p.p.m., has been shown by Garrey (2) to cause death to the pumpkinseed (*Lepomis gibbosus*) and the gold fish (*Carassius auratus*), fishes comparable in hardiness to the bluegill and bullhead; and Wiebe *et al.* (3) found that

10,000 p.p.m. of calcium chloride ($CaCl_2$) was toxic to sunfishes. Since it is known that a high chloride content (in excess of 100,000 p.p.m.) was present in these materials (4) it is only reasonable to assume that these salts are in part responsible for some of the toxicity. Many of the salts, being insoluble or only slightly soluble, undoubtedly were precipitated out in the sludge. However, since it was demonstrated in this study that the inert, slightly toxic sludge does possess high toxic values when acidified, it does constitute a menace when present in the composite treated plating solutions.

Acknowledgments

The writer is greatly indebted to Clarence Taube, Fisheries Biologist of the Institute for Fisheries Research, for his work in conducting the tests, and to Dr. A. S. Hazzard, Director of the Institute for Fisheries Research, as a consultant. Acknowledgment is also made to Manley L. Ross, of the Electrochemicals Department of the Du Pont Company, for his cooperation and suggestions during the course of the study.

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NEW TRADE WASTE BULLETIN ISSUED

The National Lime Association has announced the availability of a new 32-page publication known as Trade Waste Bulletin No. 1 entitled "The Use of Lime in Industrial Waste Treatment."

This booklet describes the various applications of lime in the treatment of different trade wastes and includes a reference bibliography which will be useful to those interested in this field.

Single complimentary copies of this new bulletin will be supplied to all engineers and chemists who address inquiries to the National Lime Association, 927 Fifteenth Street, N.W., Washington 5, D. C.

COMPRESSED YEAST WASTE TREATMENT*

I. Nature of Materials and Physical-Chemical Treatment

By Willem Rudolfs and Eugene H. Trubnick

Wastes resulting from the manufacture of compressed yeast are in many respects similar to other industrial discharges, such as those from the brewing and fermentation industries. In several instances the manufacture of yeast is only one of many "fermentation" processes carried on in a single industrial establishment. Until recently the greater part of the information available on the treatment of yeast wastes has been culled from data on wastes of a "similar" nature.

For the purpose of determining the most suitable and most economical method of treatment of yeast wastes, a program of study was inaugurated including laboratory experiments, laboratory pilot units, and large pilot plant investigations. The laboratory experiments were designed to determine the feasibility of various physical, chemical and biological methods, as well as the adaptability of the methods to the problem. The laboratory pilot units were designed to determine the effect of various factors involved, and the possibility of modifying the procedures. The large pilot plant was constructed on the basis of the laboratory findings, allowing a large measure of flexibility. It is the intention to present the findings in a series of papers.

Information Available

The amount of basic information necessary for design and operation of a complete treatment of yeast wastes is small.

In many cases, brewery and distillery wastes are marketed for use as livestock fodder (1), because of their high content of food material and growth-promoting substances. Where recovery as fodder has not been possible, disposal has been resorted to. Buswell and LeBosquet (2) have studied treatment of distillery wastes by a combination of two-stage anaerobic digesters and trickling filters. The digestion process reduced the B.O.D. from a value of 15,000 to 16,000 p.p.m. in the raw material to 1,500 to 2,000 p.p.m.; the filters further reduced the B.O.D. to an average value of 138 p.p.m. Hoover and Burr (3), by means of dilution and trickling filters, were able to effect a 90 per cent reduction in B.O.D. of molasses-alcohol wastes.

There is sufficient difference between the wastes from yeast manufacture and those from industrial processes utilizing yeast in fermentations to warrant a separate approach. Sander (4) compared lath trickling filters, activated sludge, and Emscher filters for the treatment of yeast wastes. With a combined waste of 9 parts yeast waste, 1 part strawboard waste and 30 parts water, which was neutralized and fed to a trickling filter at a loading of approximately 3,500 lb. oxygen consumed per acre-foot per day, a 51 per cent reduction in oxygen consumed was effected. Activated sludge treatment was found to produce a bulky sludge, which on microscopic examination showed a filaceous structure and predominant bacterial infection, while protozoa comprised only 3 to 5 per cent of the total micro-organisms. The submerged contact aeration, with load-

* Journal Series Paper of the New Jersey Agricultural Experiment Station, Department of Sanitation, Rutgers University, New Brunswick, N. J.

ings corresponding to 3,300 to 5,500 lb. oxygen consumed per acre-foot per day, effected reductions of from 61 to 73 per cent in oxygen consumed value, 68 to 81 per cent of volatile matter, and 64 to 80 per cent in organic nitrogen. A treatment plant was designed on the basis of Sander's work, but was never constructed.

Jensen (5) described a Danish plant consisting essentially of anaerobic digestion, intermediate ponding and trickling filters. With a raw waste containing 8,600 p.p.m. B.O.D., a reduction of 89 per cent was effected by the digestion process, 53 per cent by the ponds, and 70 per cent by the trickling filters, with an over-all reduction of 99 per cent. Although sizes of units were not given, Kiby (6), in a reference to the plant, reported that an area of 2 acres was required for this installation, which treated approximately 94,000 gal. of waste per day. The digestion produced 400 to 500 ml. of gas per gram of added volatile matter, and effected reductions of 56 per cent of total solids, 84 per cent of volatile matter, and 86 per cent of organic nitrogen. Sludge production was reported to be extremely low; the digestion plant was in operation for 4 years before it was necessary to draw sludge. A high degree of nitrification took place in the trickling filter, resulting in an effluent containing 200 to 400 p.p.m. nitrates.

Greenleaf (7) described a plant for the treatment of combined yeast and malt products wastes by sedimentation and digestion. Schlenz (8) reported on operation of this plant, treating by digestion 250,000 g.p.d. of material containing 12,000 p.p.m. total solids, 8,100 p.p.m. volatile solids and 5,000 to 10,000 p.p.m. B.O.D. With a total detention period of 7.2 days in a three-stage digester, reductions of 37 per cent in total solids, 50 per cent in volatile solids, and 90 per cent in B.O.D. were attained, with a daily production of 0.67 cu. ft. of gas per cubic foot of digester capacity. The loadings amounted to 0.104 lb. total solids, 0.071 lb. volatile solids, or 0.065 lb. B.O.D. per cubic foot of digester capacity per day.

Nature of Material to be Treated

In the manufacture of compressed yeast at the Old Bridge, N. J., plant of Anheuser-Busch, Inc., the process consists essentially of planting seed yeast in a nutrient solution and allowing it to grow under aerobic conditions until maximum cell multiplication is attained, then separating the yeast from the spent nutrient solution, compressing, and packaging. The plant effluents consist of: (1) filter residues resulting from the preparation of the nutrient solution, (2) spent nutrients, (3) wash waters, (4) filter press effluents, (5) cooling waters.

The rate of flow and the concentration of the combined wastes vary considerably through the day, as indicated in Figure 1. The peaks in B.O.D. occur when spent nutrient, the strongest portion of the wastes, is flowing. The suspended solids content remains relatively constant, except when filters are being cleaned. Because the various phases of the manufacturing process discharge liquids at widely divergent intervals, no correlation exists between variations in rate of flow and variations in strength of the combined wastes.

The filter residues are high in phosphate and protein, and contain large quantities of inert filter aid. They are not amenable to anaerobic digestion, and are not highly putrescible.

The spent nutrient is the effluent from the centrifugation of the yeast after growth. This material is brown in color, and has a yeasty odor. Evaporation is difficult because the solids are highly hygroscopic. The solids are almost entirely dissolved and colloidal; the suspended solids content is seldom above 200 p.p.m. This waste has approximately the following com-

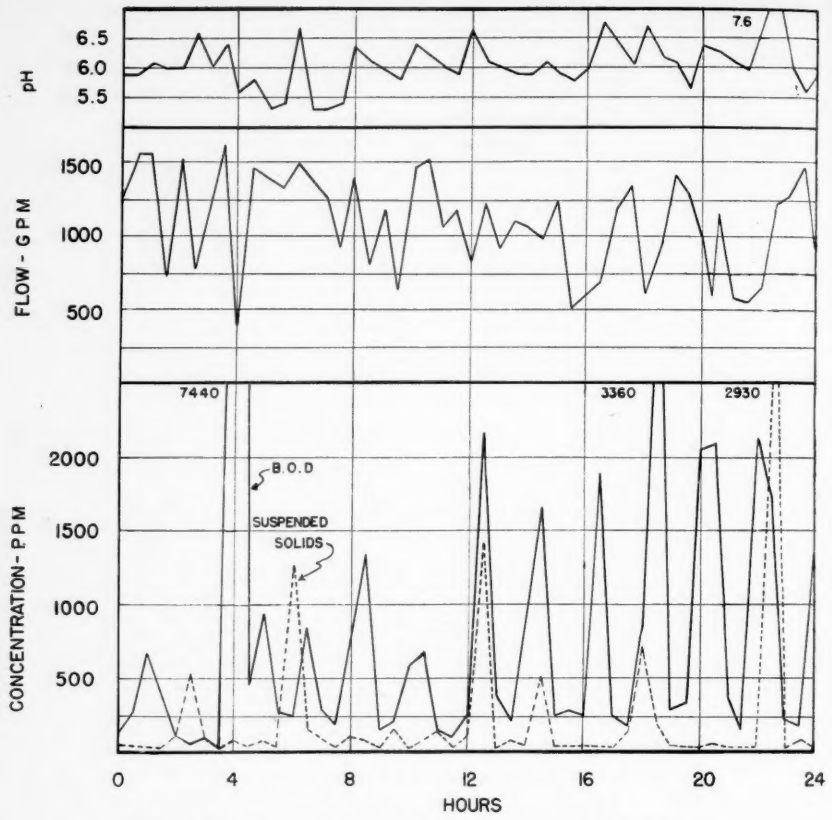

FIGURE 1.—Typical 24-hour flow of combined yeast wastes.

position (all except pH expressed as p.p.m.):

Total Solids	10,000–20,000
Suspended Solids	50–200
Volatile Solids	7,000–15,000
Total Nitrogen	800–900
Organic Nitrogen	500–700
Total Carbon	3,800–5,500
Organic Carbon	3,700–5,300
5-day, 20° B.O.D.	2,000–15,000
Sulphate (as (SO_4)	2,000–2,500
Phosphate (as P_2O_5)	20–140
pH	4.5–6.5

The wash waters derive from washing of the centrifuged yeast with clear water and re-passing through the centrifuge. They consist of diluted spent nutrient. Although the concentration of the wash water decreases progressively during a given batch, a composite sample of wash is approximately half the strength of the spent nutrient. The filter press effluent, resulting from filtration of the centrifuged and washed yeast, is of the same strength as the weaker portions of the wash water.

Utilization of oxygen by the spent nutrient, as reflected in the 20-day B.O.D. curve, is indicated in Figure 2. The oxygen utilization is slow for the first day of incubation, accelerates for the next four days, and then progresses at a slower rate again until the thirteenth day, when a secondary steep inflection occurs, typical of sewage oxygen utilization curves and usu-

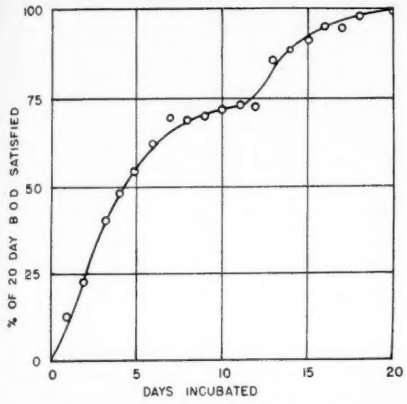

FIGURE 2.—Oxygen utilization of spent nutrients.

ally attributed to active nitrification. The same type of curve is found with samples seeded with cotton-filtered domestic sewage as with unseeded samples.

In the earlier stages of incubation, the rate of oxygen utilization appears to be affected by the concentration of the spent nutrient in the dilution water, and to be altered by the presence of seed in the form of domestic sewage. Data in Table I indicate that after 5 hours' incubation, the B.O.D. varies over a sliding scale from 134 to 300 p.p.m., as the concentration is decreased from 5.0 per cent to 0.1 per cent. After 24 hour's incubation, the B.O.D. varies similarly from 435 to 1,000 p.p.m. as the concentration is decreased from 1.0 to 0.05 per cent. Beyond 24 hours, the concentration has no significant effect on the B.O.D. value. No attempt was made to determine the cause of the differences observed with changes in concentration, which might conceivably be due to critical differences in oxygen tension, or to "toxic conditions" present at higher concentrations or to phenomena involved with the establishment of the flora in the presence of dissolved oxygen.

The addition of 1 ml. of cotton-filtered domestic sewage per liter of dilution water, as seed, materially increased the 1- and 2-day B.O.D. values of the spent nutrient, resulting in values approximately twice as great as those of the unseeded material. This difference is not evident in the case of the 5-day values, where the B.O.D. of the seeded material is essentially the same as that of the unseeded sample. Apparently the native flora of the spent nutrient is not established in the presence of dissolved oxygen so rapidly as is the sewage flora immediately after incubation, but after 2 days becomes just as active as do the organisms in the sewage.

The velocity constant K of the oxygenation reaction of spent nutrient,

TABLE I.—Effect of Concentration and Seed on B.O.D. Values of Spent Nutrient

Incubation Time	5 Hours		1 Day		2 Days		5 Days	
Concentration (%)	Unseeded (p.p.m.)	Seeded (p.p.m.)	Unseeded (p.p.m.)	Seeded (p.p.m.)	Unseeded (p.p.m.)	Seeded (p.p.m.)	Unseeded (p.p.m.)	Seeded (p.p.m.)
0.025	—	—	—	—	1600	3000	3800	4000
0.05	—	—	—	1000	1300	2800	3800	4400
0.1	300	—	850	900	—	—	3450	3700
0.15	233	233	567	967	1430	2330	4500	3870
0.2	250	225	575	900	1600	2435	—	—
0.4	212	238	425	650	—	—	—	—
0.8	212	206	562	544	—	—	—	—
1.0	200	195	435	540	—	—	—	—
2.0	175	182	—	—	—	—	—	—
5.0	134	139	—	—	—	—	—	—
Average	215	203	569	786	1482	2639	3888	3992

TABLE II.—Septicization of Spent Nutrient and Wash Water

Days	B.O.D. (p.p.m.)				Increase in B.O.D. (%)				Average (%)
	Spent Nutrient		Wash Water		Spent Nutrient		Wash Water		
	Exposed	Closed	Exposed	Closed	Exposed	Closed	Exposed	Closed	
0	2400	2400	720	720	—	—	—	—	—
1	2400	2260	660	730	0	−5.8	−8.3	1.4	−3.2
3	2970	3360	735	780	23.8	40.0	2.1	8.3	18.6
5	3600	—	1110	1110	50.0	—	54.2	54.2	52.8
7	4920	5100	1440	1380	105.0	112.5	100.0	94.5	103.0

calculated from 10-day B.O.D. curves by the method outlined by Thomas (9), was found to lie between 0.022 and 0.096, with an average of 0.063 for unseeded samples; and between 0.078 and 0.217, with an average of 0.110, for seeded samples. These differences in K values between the seeded and unseeded samples appear to be caused by greater activity of the seeded samples between the second and fourth day of incubation.

Both the spent nutrient and the wash waters are highly putrescible. The B.O.D. of both materials, whether allowed to stand in open or in closed containers, rises materially upon standing, so that the value after 5 to 7 days is double that of the fresh material. The rate of B.O.D. increase is graphically shown in Table II and Figure 3.

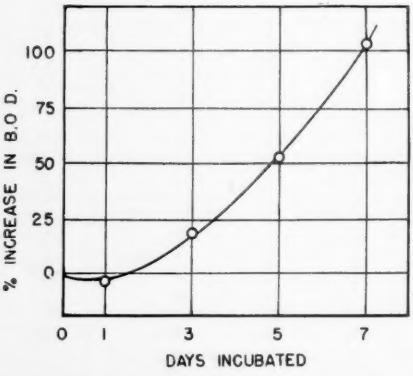

FIGURE 3.—Effect of septicization of yeast plant effluents.

In connection with the possibility of separate treatment of waste fractions with higher oxygen demand values, or pre-treatment of the stronger material before combined treatment of all wastes was practiced, it was of interest to determine the B.O.D. and oxygen consumed of the various fractions. As an illustration the results on two samples of various portions are:

Waste	B.O.D. (p.p.m.)		O.C. (p.p.m.)	
Spent nutrients	3125	4250	4560	5400
First wash	650	850	1030	1400
Second wash	215	600	336	800
Press effluent	817	600	1250	800

The B.O.D. and O.C. values of the total wash water amount to about 15 per cent of the spent nutrients. Determinations of B.O.D. and O.C. values of 18 different samples showed that the average ratio between B.O.D. and O.C. was 1:1.18.

Laboratory Experiments

Laboratory experiments were conducted to study the application of various possible methods of treatment to compressed yeast wastes, and particularly to evolve a specific, economical method for use in large scale operations. Since published information pertaining to physical and chemical treatment was not available, an attempt was made to determine the effect of electrodialysis and of usual inorganic coagulants and various solvents

on the clarification and purification of the wastes.

Electrodialysis

Treatment by electrodialysis has been shown to be very effective when considerable quantities of suspended solids are present in the waste. Treatment by electrodialysis of soluble organic waste is not very effective, but could conceivably be of importance as a method of pretreatment of strong material (10).

A considerable amount of work was done by electrodialyzing spent nutrients in a three-chamber dialysis cell, using closely woven asbestos membranes, and iron cathodes and carbon and/or aluminum anodes. The source of current was a 24-volt rectifier.

Some condensed results obtained with various electrodes, differences in charges, and combinations are shown in Table III. The reductions in oxygen consumed values varied from 4 to 40 per cent in from 7 to 24 hours' dialysis, depending upon the type of electrode used. Where aluminum anodes were used, sludge formation occurred. The sludges filtered easily, producing, without additions of chemicals, cakes of about 79 per cent moisture.

In an effort to determine which substances were precipitated by dialysis, a solids balance was made by determining total solids, ash, O.C., total carbon, total N, amino-N, and ammonia-N in the raw spent nutrients, sludge, supernatant liquor and dialysate water. Partial results are shown in Table IV. About 25 per cent of the original total nitrogen was precipitated in the sludge, leaving about 50 per cent in the supernatant liquor. About 20 per cent of the amino-N was found in the sludge.

Chemical Treatment

Chemical coagulation of sewage removes primarily suspended solids and a portion of the B.O.D. Little B.O.D. caused by soluble substances is re-

TABLE III.—Electrodialysis of Spent Nutrients

Electrode in Spent Nutrient Chamber (Material)	Charge	Volume Ratio, SN:Water	Time of Dialysis (hr.)	pH of End Prod.	Removal of Oxygen Consumed (%)
None[1]	None	1:2	24	6.3	33
Carbon	+	1:2	9	2.2	4
Carbon	+	1:2	9	2.2	17
Aluminum	+	1:2	6	4.7	30
Aluminum	+	2:1	12	4.7	33
C, then Al[2]	+	1:2	12	4.0	36
C, then Al[2]	+	2:1	12	4.0	29
Iron	−	1:2	7	9.3	40
Iron	−	2:1	8	11.4	29

[1] SN in center chamber; electrodes in water in outer chambers.
[2] Carbon electrode used for 6 hours, then changed to aluminum.

TABLE IV.—Partial Results Obtained After Dialyses (Per Liter)

	Spent Nutrient	Supernatant	Sludge	Dialysate	Decrease
O.C. (mg.)	4325	1282	2660	70	7.2
Total N[1] (gm.)	6.26	3.43	1.55	0.44	13.4
Amino-N[1] (gm.)	0.862	0.718	0.057	0.044	5.0
Ammonia-N (gm.)	0.375	0.300	0	0.060	4.0

[1] As protein.

moved from the liquor unless chemicals are added in excessive quantities, causing precipitation. It could be expected that material such as spent nutrients containing very large amounts of soluble substances would not readily respond to the usual standard coagulants. Nevertheless, coagulants such as ferric chloride, ferrous sulfate, alum and alcar were tried in varying amounts (from 5 to 1,000 p.p.m.) and at pH values ranging from 2 to 11 as a basis for comparison with a number of organic solvents and organic coagulants. Only small amounts of solids were precipitated, and the degree of clarification was considered insufficient to utilize coagulation as pretreatment in relation to the cost entailed.

Similar results were obtained with organic coagulants such as ethyl alcohol, acetone, carbon tetrachloride, toluene, benzine, ether, methyl or butyl alcohol.

Summary

Compressed yeast wastes contain from 7,000 to 9,000 p.p.m. volatile solids, nearly all in solution. The B.O.D. is high, varying from 2,000 to 15,000 p.p.m., and the sulfate content varies from 2,000 to 2,500 p.p.m. The material is highly putrescible, increasing rapidly in B.O.D. upon standing.

The oxygen utilization proceeds in a manner similar to sewage, with an average K value of 0.063 for unseeded and 0.110 for seeded spent nutrients. The oxygen consuming value is higher than the B.O.D. values.

Laboratory experiments with electrodialysis showed that with the best electrodes about 40 per cent of the oxygen consuming material could be removed. Spent nutrients treated with various inorganic and organic coagulants showed no material precipitation or clarification.

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THE OPERATOR'S CORNER

CONDUCTED BY S. C. MARTIN

ON BECOMING A FULL MAN

Having to apply the knowledge and skills from so many fields to the problems of our own, we sewage works men too often devote our energy to collecting information rather than acquiring understanding. We become dabblers in many fields rather than serious students of any one. Most of us are full of information but have precious little understanding of fundamentals.

One reason why information is more prevalent than understanding is the lazy habit of promiscuous reading practiced by so many. Nearly all operators feel some compulsion towards self-improvement but their only efforts in this direction are irregular periods of unrelated reading—professional magazine articles, trade bulletins, occasionally a few chapters in a technical book, sometimes even a "high-powered" research article in the JOURNAL! But seldom is this reading done comprehensively on any one phase of sewage treatment.

The pattern of technical reading frequently is similar to that of chickens hunting breakfast, and as a result minds become stuffed with unrelated and undigested kernels of this-or-that. Unlike chickens, we lack the instinct to stop and digest what has been swallowed, but go blithely on, gobbling down whatever strikes our fancy.

With little more effort than that now expended in hit-or-miss reading, most operators could deepen their knowledge by a planned program of reading, in which a subject or problem is selected and thoroughly studied. For example, if sludge digestion is your immediate problem why not during the long winter evenings ahead read everything available about sludge digestion? Review articles in the back issues of the JOURNAL and other magazines in the field. Read all that can be found concerning this problem. Tackle the theoretical discussions as well as those dealing with practice. Abstract the articles that seem to answer the questions that puzzle you most. Critically analyze what you read, weighing it against the ideas of others and your own experience. Several weeks of such reading and study will surely develop a much better understanding of sludge digestion and its related problems. Once started, this method of reading will always be continued.

Education and mental ability, of course, will always limit the extent of our understanding, but planned, thoughtful reading and study will clear up many hazy ideas and will develop confidence in solving operation problems.

The great English philosopher Lord Bacon said: "Reading maketh a full man." Jack-rabbit reading will fill one full of information, but if understanding is desired, invest your spare time in planned, purposeful reading.

S. C. M.

CENTRAL STATES SEWAGE WORKS ASSOCIATION 1948 OPERATORS' BREAKFAST FORUM *

L. S. KRAUS, *Chairman*

First Vice President, Central States Sewage Works Assn.; Chemist, Greater Peoria Sanitary and Sewage Disposal District, Peoria, Ill.

SLUDGE DIGESTION

Chairman Kraus: I shall ask Professor Bloodgood to open the discussion by outlining the sludge digestion process as he might for his students.

D. E. Bloodgood, Associate Professor, Purdue University, West La Fayette, Ind.: I call sludge digestion a "first team and second team" process. The first team starts in the digestion tank and does something to the sludge. It convérts some of the organic matter into volatile acids. The second team then comes along and picks up the volatile acids and converts them either into gas or into liquid. Trouble results when the first team and the second team get out of step, and the second team can't keep up while the first team keeps on going. The sludge then gets sour, with too many volatile acids.

According to many operators, the way to cure an upset digester is to reduce the volatile acids by the addition of lime, somewhat after the fashion of taking soda for a stomach upset, which isn't, to my way of thinking, very practical. I don't believe that just adding lime to a digestion tank is worth very much. It gets rid of the acids, but it doesn't remedy the situation. It doesn't give the second team a chance.

Use of Lime

W. W. Mathews, Superintendent, Gary (Ind.) Sanitary District: You will remember, Mr. Schlenz and Dr. Buswell wrote a fine article on what happens when you put lime in a digester.

We never use lime to control digester pH. In fact, we never pay any attention to the pH. At Gary, gas production will vary from a high to a low, and when it gets low it costs us money.

Each of the five primary digesters, of 1,030,000-gal. capacity, has a normal gas production of 40,000 cu. ft. per day. When two of these drop in gas production to as low as 25,000 cu. ft. per day, as occasionally occurs, the monetary loss from reduced power production is considerable.

We have found that when the gas production of a digester drops from an average 40,000 to, say, 25,000 cu. ft. per day, normal production can be restored in 48 hours by adding 100 lb. of hydrated lime.

Can anyone explain to me what happens when we put 100 lb. of lime in a million-gallon digester, and why does it bring the gas production back? It would take a very delicate test to find the effect of 100 lb. of lime after it is dispersed through that million gallons of sludge. But the treatment never fails to work as long as there are solids in the digester. It doesn't work, of course, when there is a rain and all the sewage solids are going to the river at storm water overflows, and the raw sewage B.O.D. is about 20 p.p.m. with the suspended solids as low as 30 to 40 p.p.m.

Mr. Bloodgood: What made the gas production fall?

Mr. Mathews: We don't know. We have run volatile acid tests but obtained no useable information.

We have the same amount of pumpage to each of the five digesters, within

* From transcript as reported during the Operators' Breakfast, Twenty-First Annual Meeting of the Central States Sewage Works Assn., Milwaukee, Wis., June 18–19, 1948.

reasonable limits. One or more will begin to fall off in gas production until the decrease is as much as 15,000 cu. ft. per day. When this occurs we just put 100 lb. of lime in the tank and in 48 hours gas production is back where it was before.

Walter A. Sperry, Superintendent, Aurora (Ill.) Sanitary District: How do you disperse that lime?

Mr. Mathews: It is mixed in solution in a mixing tank that holds 200 to 300 gal., and then pumped into the digester with a raw sludge pump. The digester agitators, impellers, and paddle wheels disperse it through the tank.

Chairman Kraus: Mathews, have you ever tried not adding the lime?

Mr. Mathews: Yes. We have waited as long as 2 or 3 weeks for the gas production to return without liming, with negative results. Meanwhile, gas production of the other digesters was normal.

Digester Loading and Gas Production

Chairman Kraus: A million-gallon tank producing 25,000 to 40,000 cu. ft. of gas a day, to my way of thinking, has an extremely light load on it, and it seems to me that you ought to increase the load on some of the digesters so that you have a very rapid digestion rate rather than a very slow one. Your digestion period is probably in the order of 60 days.

If you would decrease the period to about 10 days, you would have a more rapid evolution of gas and you wouldn't have to worry about adding lime.

Mr. Mathews: Let me controvert that. We just had one of the digesters out of service for about 3 months, which placed all the load on the other four digesters. During this time less gas was produced by the four heavier loaded digesters than was normally produced by all five.

H. T. Rudgal, Superintendent, Sewage Treatment Plant, Kenosha, Wis.: Our plant load has doubled in the last 2 weeks. Before this we used about 11 cu. ft. of gas per lb. of volatile solids as a standard for good digestion. Since the digester load has been increased, gas production is down to 7 or 8 cu. ft. per lb. volatile solids. There definitely is a relationship between the loading and the efficiency of digesters.

It has been suggested that the Gary digester loading be increased to prevent reduction in gas production. I don't think that is the answer. More digester capacity provides a longer period to digest the solids and, ultimately, more gas will be produced because the digestion will be more complete.

W. D. Hatfield, Superintendent, Decatur (Ill.) Sanitary District: When was the last digester trouble experienced?

Mr. Mathews: From the middle of March to the middle of June.

Dr. Hatfield: That is about the period when rain and other factors lower gas production every year. Perhaps a seasonal condition caused the trouble.

Mr. Mathews: Gas production has also dropped during drouth periods when flow conditions were as uniform as is possible with combined sewers.

George E. Symons, Associate Editor, Water & Sewage Works, New York, N. Y.: How did the drop this year compare with last year for the same period?

Mr. Mathews: It was about the same.

J. D. Walker, President, Walker Process Equipment, Inc., Aurora, Ill.: At many small plants I have observed that a little lime added to the sludge when the digester has gone acid seemed to have a beneficial effect, but that the addition of lime can be overdone. We have often cautioned plant operators against adding too much lime. When the delicately balanced digestive forces are upset, the addition of raw sludge seems to aggravate a bad condition, but a little lime can help the raw sludge remain alkaline and

can easily be the factor that will restore balance to the digestive process.

C. C. Larson, Chemist, Springfield (Ill.) Sanitary District: When lime is added and the acid is neutralized you are asking for more acid to form, and instead of correcting the condition you just make it worse.

Mr. Walker: I think that is true if you neutralize the entire tank.

Chairman Kraus: The digestion process is a combination of processes. First, fermentation reduces the solids, produces the gas, and removes some of the compounds that would decompose with objectionable odor. The fermentation takes place in a rather short time.

We also expect sludge digestion to produce a concentrated sludge, and that is a long-time process. My experience with activated sludge has indicated that about 90 per cent of the initial fermentation process is completed in something like 10 days. However, if 10 per cent solids are required for the final sludge disposal process, the period necessary for coalescence of those solids is an extremely long one. In an activated sludge plant I would judge it to be something like 200 days. In 100 days you might get 5 per cent solids, a good value if you are digesting activated sludge.

There is a great difference of opinion as to how the digestion process should be carried out. Should it be done in a single stage, getting the fermentation, the reduction of total solids, and the coalescence in a single tank? Or should it be done rapidly in a small tank, followed by a very large tank for separation and storage? Or should a very small tank be used and only the fermentation stage developed, with the solids concentrated and treated outside the digester as dilute sludge?

Stage Digestion

George Martin, Superintendent, Green Bay (Wis.) Metropolitan Sewerage District: We started out with all primary digesters. We have four of them. We found we couldn't get a good supernatant liquor operating that way. So we had to go to two-stage digestion. It makes operating much easier, and I certainly think a much better supernatant liquor can be obtained that way. Whether or not it is justified from a cost standpoint, I don't know.

Chairman Kraus: What is the purpose of concentrating the sludge in your plant?

Mr. Martin: If we do not get concentration, the high solids in the returning supernatant liquor upset the primary clarifiers, making them gas and bubble.

Mr. Walker: Why put untreated supernatant liquor in a primary clarifier anyway? Why aggravate and spoil a good sedimentation condition by adding a liquor which encourages putrefaction?

Chairman Kraus: I am quite in agreement with you that it doesn't belong in the primary sedimentation tanks.

Mr. Martin: You have to put it some place!

Mr. Larson: I am a little embarrassed and disappointed to think that we buy all these digesters and equipment just to get rid of odors. Can't we find some other justification for our digestion tanks?

On this subject of supernatant liquor, did Mr. Martin say he had to go to two-stage digestion to get better supernatant liquor? Did it improve the quality of the supernatant liquor?

Mr. Martin: Materially.

Mr. Larson: We don't get much better liquor with two-stage digestion than we did with single stage. After about 20 years of experience I am still undecided as to the best method of supernatant disposal.

Supernatant Liquor Disposal

Dr. Hatfield: Why don't you put it back in the activated sludge units? We have been doing that for so long that I just thought there was no supernatant liquor problem any more. I wish I could get twice as much supernatant liquor in my activated sludge plant.

We use about the first quarter of the aerators for reaeration of the sludge. Supernatant liquor returned there helps the sludge index immensely. I think it is due to the ammonia nitrogen that is in the liquor. I believe Mr. Kraus returns supernatant that is almost sludge.

Under our unusual conditions, we get a very good, clear supernatant. By returning all the supernatant possible to the sludge reaeration tank we keep the sludge index down to about 60 the year around. There isn't any bulking problem then, and we solve two problems, bulking and supernatant liquor disposal.

Theodore F. Wisniewski, Sanitary Engineer, Wisconsin State Board of Health, Madison, Wis.: At Jefferson Junction, Wis. we have a malting plant which has a screening unit, a trickling filter, and digestion facilities. In order to increase the amount of nitrogen going to the filters it was decided that instead of buying chemicals to supply the nitrogen, supernatant liquor from the digesters should be returned directly to the filter recirculation line and pumped to the filters.

The situation there is unique. They have been operating almost 2 years, getting good digestion and running all supernatant liquor directly to the filter. Because of the special type of waste there, it hasn't been necessary to draw sludge from the digester to the drying beds. They just haven't had to draw any off.

Harry Schlenz, President, Pacific Flush Tank Company, Chicago Ill.: Jefferson Junction started out on digestion for only one purpose. They could not get a drying sludge, and they found that the farmers wouldn't take wet sludge, so they put in digesters to get a sludge which would dry. However, they put their heavy digester liquor on the filter bed, and now they don't get any sludge. They think they have been cheated a little bit.

I suggested that this heavy supernatant should be put on the filter beds at Jefferson Junction because of the very heavy growth continually on the filter beds due to the malt house waste. The supernatant, I thought, would cause the beds to unload continuously, rather than seasonally. That is exactly what happened.

When we found a similar supernatant liquor problem at the Riverside, Calif., municipal plant, we hesitated to recommend the Jefferson Junction procedure because of the malt house waste there. We did recommend it, however, and a week later the operator called long distance and said, "That's the trick!"

S. E. Hook, Superintendent, Ft. Sheridan (Ill.) Sewage Treatment Plant: At Ft. Sheridan we have two-stage digestion. For 4 or 5 years we kept a temperature of 85° to 90° F. in the second-stage digester. The last 2 years the plant load decreased to such an extent that only enough gas is available to heat the first-stage digester. Consequently the supernatant liquor returned to the primary settling tanks has a temperature of 45° to 50° F. The return of this relative cold supernatant, having a solids content of 2 to 3 per cent, has not caused any objectionable condition in the primary tank. However, when the secondary digester was being heated and 85° to 90° F. supernatant liquor was wasted to the primary tanks, we had a great deal of trouble with septic action and rising sludge.

Stanley T. Barker, Chief, Bureau of Sewage and Waste Disposal, New

York State Department of Health, Albany, N. Y.: Occasionally I have to talk at short schools for operators. I have told operators that the digester was the treatment process for sludge. Am I wrong?

Sludge Digestion Objectives

Chairman Kraus: We would like to get rid of sludge in a hurry and not have numerous tanks. It is desirable to put sludge on drying beds and dry it in 24 hours. The reason we don't do it is because of the odor problem. I may be wrong, but I believe that everything else connected with sludge digestion is just incidental to that little problem. If we could use drying beds or filters directly, and not have an odor problem, I believe it would be economical.

Mr. Barker: Wouldn't you say we treat sewage to prevent odors?

Mr. Schlenz: Each individual problem sets up the reason for sludge digestion. For example, at Portland, Ore., they are constructing settling tanks and digesters. After the solids are digested they will be discharged to the river along with the plant effluent.

I discussed with the Portland project engineers the proposal to use two-stage digestion for the sole purpose of producing a good supernatant liquor. I asked, "Why get a good supernatant if you are going to discharge it and the digested sludge to the river?" I indicated they should obtain rapid digestion.

The Portland objective is destruction of solids, because everything that won't be destroyed will go into the river anyway. Boston has the same situation, as does New York City. They want to destroy as much as possible because the remainder must be barged to sea.

Walter M. Kunsch, Engineer-Manager, Urbana-Champaign (Ill.) Sanitary District: Returning to the why's of digestion, getting rid of the odor is not the only reason for digestion. The reasons depend on the local situation. Digestion not only eliminates odors, but also changes the character of the solids so that disposal can be accomplished on the plant grounds, if there is room, or the solids can be used as fertilizer.

Effect of Clay Waste on Stage Digestion

Mr. Sperry: We began our Aurora operation with single-stage digesters and never had a supernatant problem of any kind. The liquor has always been returned to the raw sewage channel.

About 1936 we converted our digesters to a two-stage system, using the No. 1 digester for primary digestion and transferring sludge alternately to the two secondary digesters. We still had no supernatant problem.

When we acquired a secondary settling basin in 1936, I could not see the logic of putting final tank sludge back into the primary tanks to be pumped to the digesters. Therefore, our practice has consistently been to return this sludge, from the trickling filters to the two secondary digesters.

The practice of many operators is to withdraw digested sludge to drying beds in small amounts. Our practice is to allow a digester to fill up to what we call the "supernatant overflow line," and then we draw the whole tank to the beds, retaining about 4 ft. in the bottom for seed. Then we immediately fill the digester with raw sewage. Within a few hours the digester is back on the line, and in 2 to 4 days gas production is back to normal. Thus, when we draw sludge to the beds we discharge about 30,000 cu. ft. and fill up four to five sludge beds.

As long as the digester operates with the sludge line below the supernatant overflow pipe, our supernatant is practically clear water, half a per cent solids, or so. When the digester fills up we may have a few days of pretty

bad operation, due to sludge coming back into the clarifiers.

We did not fully attain our objective when we went to two-stage digestion, because we found that the primary transfer sludge did not concentrate in the secondary digesters, particularly after we started pumping the lighter, more flocculent final settling tank sludge to the secondary digester.

Since the change to two-stage digestion we have been vexed with short runs on the secondary digesters of 35, 40, or 50 days, and an occasional surprise run of 80 days. But this meant that the sludge beds had to be cleaned about eight times a year. This did not matter so much when an ample supply of labor was available but today it is a problem.

We have been guilty of some things that I wish we hadn't done, but we were forced to do them because we had no other alternative. When the digesters and sludge beds were full, we have been guilty of using what we call our "black market" pipe, and discharging digested sludge directly to the river.

Last year the largest wallpaper printing plant in the world, a plant with 40 wallpaper printing machines, located adjacent to our sewage plant. Several conferences were held with the officials of that plant, and we studied the wastes from wallpaper printing plants in Chicago and Joliet. These wastes are of relatively small volume but contain from 30 to 40 tons of clay per million gallons, with a fair percentage of protein and casein content. The volume is approximately 50,000 to 60,000 gal. per day, so that the total monthly discharge of the plant would only be between 1 to 2 m.g., but carrying 35 to 70 tons of clay. Company officials were advised that they must provide their own treatment plant.

They agreed to construct such a plant, and a small package-type plant capable of reducing the clay content to 100 p.p.m. was suggested. We paid no attention to the B.O.D. content, because we had plenty of capacity to handle it.

The wall paper company provided a well designed plant to remove clay. Wallpaper printing started late last summer but the little clay removal plant didn't do very well. Nothing objectionable, however, seemed to happen at our sewage plant. The wallpaper printing waste is highly colored. At times our plant influent is green, blue, yellow, etc. Sometimes it is terrifically loaded with clay.

In February, 1948, we discharged our secondary digesters and, to our amazement, those digesters had run about 120 days since the last emptying. I believe the sludge was about 8 per cent solids. Previously only 35- to 50-day digester runs were obtained. The improvement was attributed to the clay.

Ten days ago we discharged the secondary digesters for the second time since the clay waste has been coming to our plant. In February both digesters reached the overflow level at the same time because we fed them uniformly. This last time sampling showed that one digester was up to the overflow line but that the other one was many days away from that level. I don't know why, because the same amount of sludge has been transferred to each digester. Only one digester was discharged, the sludge averaging 10 per cent solids. We are reasonably sure now that the effect of the clay will more than offset that of the light, flocculent final tank sludge. Here, apparently, is an example of an industrial waste that has been beneficial to a sewage works, rather than detrimental.

There is another interesting story about this wallpaper plant waste. The company procrastinated terribly in getting their waste treatment plant in effective operation. We ran some coagulation studies on this waste and

found that even with optimum pH conditions about 40 to 50 grains of alum were required for good coagulation.

Quite by accident, I happened to pour some acid into one of the samples, and I almost heard the solids fall. Later we found that when the pH was adjusted to 5.0 by the addition of acid, sharp coagulation occurred due to the presence of the protein and casein. The explanation is that optimum coagulation of protein and casein occurs at their isoelectric point, which is 4.8 for protein. Apparently the wallpaper waste treatment problem has been solved as far as solids removal is concerned.

The other day I decided that perhaps we had better soft pedal our request for better operation of the wallpaper waste treatment plant. As long as they get a reasonable removal of the clay, we'll let things stand because I believe now we would like to have some of that clay.

Digester Capacities

Chairman Kraus: One of our topics for discussion is the design of digesters. I have the notion that perhaps instead of using cubic feet per capita as the basis of design, the standard should be something more realistic, such as number of days retention of the sludge.

Mr. Barker: Mr. R. S. Rankin, of the Dorr Company, has written an article on the subject of a logical approach to the selection of digester sizes.* Mr. Rankin's idea is that the digester size should be determined by providing the maximum detention affordable for the wet sludge volume actually pumped. That means that greater digester capacity is needed for a wet sludge than for one of lower moisture content. Thus, if the designing engineer can assume in advance that sludge of 5 per cent solids will be handled, he can provide digestion capacity for 30, 40, or 50 days retention and be fairly sure the digesters will operate without much trouble. If, however, he can provide capacity for only 20 to 30 days retention, the digesters can be expected to operate with considerable difficulty. Sufficient detention of the wet sludge volume pumped to the digester must be provided for satisfactory digester operation.

Someone from Buffalo, N. Y., should discuss what happens when only a relatively small digester detention capacity is available. We were told yesterday about the difficulties of handling partially digested sludge.

Discharge of Digested Sludge to River

Mr. Symons: The digesters at Buffalo, N. Y. were designed for about 0.97 cu. ft. per capita. That is not very large. That was the total capacity. Then we operated with a free board of 3 or 4 ft. that brings the capacity down to about 0.85 cu. ft. or thereabouts. We loaded those digesters with not 0.2 lb. per capita of suspended solids, but with about 0.36 lb. and we got a condition that produced scum to the extent of as much as 20 ft. of "top sludge."

Gas production ran about 45 cu. ft. per sq. ft. per day, which means it is really going. There was an average scum depth of 9 to 12 ft. of about 20 to 23 per cent solids.

Digestion capacity design was for about 21 days' detention, the plan being that this capacity would provide partial digestion. If the sludge could go to the vacuum filters and be conditioned, it would save the cost of putting in larger tanks. The sludge was to be burned, anyway.

Gas production was good and digestion fairly complete. The volatile matter was reduced from 60 to 70 per cent to about 45, which isn't bad digestion. Sludge solids in the tank run about 8

* "Digester Capacity Requirements." By R. S. Rankin. THIS JOURNAL, **20**, 3, 478 (May, 1948).

per cent in the liquid phase. There was no supernatant liquor.

Experiments at Decatur, Ill. indicated that 50 per cent of the gas came off in the first 24 hours. This was confirmed by experiments at the University of Illinois. With partial digestion greater digestion is obtained than would be expected. A sludge will not be obtained, however, which will dewater readily.

At Buffalo, in the summertime digester liquor was returned to the primary clarifiers. It wasn't supernatant liquor. It ran 6 per cent solids, which meant that we were carrying a part of the sludge load in the settling tanks. It seeded the incoming sludge nicely. Only a couple of mornings ago somebody told me about operating a primary settling tank so that there would be a little septic action. The point is, you can operate that way if you don't mind a little sludge going over the weirs. Everyone who has worked at the Buffalo plant agrees that there are other factors which contribute to the production of excessive digester scum, but that the high rate of gas production and the short digester detention period are also important factors.

Walter Sperry said he used a "black market" pipe for discharging digested sludge directly to the river. Larson rather shamefacedly admitted he did the same with digester liquor. Now, I want to throw out the thought to you state sanitary engineers that this is being done at a number of places, and that it is being recommended by designing engineers. Atlanta, Georgia, does it regularly, and has for years. They dump digested sludge into the river at night because at night the flow is low and the solids concentration of the effluent is also low. It doesn't bother the river. The sludge disappears a half mile or so downstream, as does the effect of the B.O.D.

Rawn and Candel, of California, have written a paper about discharging digested sludge to outlet streams. Schlenz has already mentioned the proposal for the Portland, Ore. design and the Boston and New York situations.

You fellows peek around, and I think you will find some other places are doing this, and it may not be as bad as you think.

I think one of the worst features of the idea—and the same applies to sludge incineration—is that it is contrary to the laws of conservation. We are wasting something which has value.

There is a man up in New York who is a well known consulting engineer to packaging companies. He has been making speeches before Rotary Clubs, etc., telling of his plan to recover all of the sewage treatment works sludge for fertilizer. His design ideas, etc. are impracticable and he is out of his field in estimating quantities. But he has a good thought—conservation. Instead of dumping sludge in the river, or burning it up, or just throwing it away, why don't you look for some place you can use it?

Mr. Sperry: About this discharge of digested sludge to the river, I would like to say that I sat down with my State Board of Health authorities, and explained the whole situation, made my confession, so there was nothing under the hat about it.

I once proposed this discharge of digested sludge to Reidesel of the Minnesota State Health Department as a sort of hypothetical problem. He didn't think it was good at all. After explaining that I had no lagoon or other area I could utilize and that it was either discharge sludge to the river or quit operating, he said "I don't think it is so bad.

Mr. Bloodgood: I notice Sperry had to go to another state to get the Board of Health to say that.

Mr. Larson: Abel Wolman wrote a paper several years ago in which he discussed this matter. While some of us confess to being bad boys, there is no doubt that this sort of thing could

get out of hand if it were used indiscriminately. Wolman, indicated that such practice should be predicated on a study of the outlet stream.

If there is sufficient dilution in the receiving stream to get by with practices of this kind occasionally, there is no particular objection to it. Why polish the effluent to a point that is absurd, and have all these plant operating troubles? If the stream is of sufficient size that it can take somewhat of a load, I don't believe there is any objection. It strikes me that the bottom lands downstream are going to benefit by the sludge just as much as the farmers who haul it out.

W. H. Wisely, Executive Secretary-Editor, Federation of Sewage Works Associations: This talk of "black market" pipes for discharging sludge and supernatant to the outlet stream is particularly disturbing to me— possibly because of my state health department background. I am familiar with the planned procedures at Portland and Boston, but may I point out that the Columbia River, and the Atlantic Ocean are fair-sized bodies of water. Even where such unlimited dilution is available, I have yet to be convinced that it is logical to build a sedimentation and digestion plant to remove three-fourths of the volatile matter in the settleable solids.

Possibly we have come to a more liberal definition of an "emergency" as justification for such measures as "black market" pipes. The discharge of sludge—digested or not—to a stream is to me an admission of complete defeat in the solution of an operation problem. I am certain that the practice can be avoided by resort to other temporary sludge disposal methods, and that such other methods are well worth the extra trouble and cost they may involve.

Philip F. Morgan, National Council for Stream Improvement, Kalamazoo, Mich.: I visited a plant several years ago in the southern part of the country. It was a complete treatment plant—activated sludge and primary treatment with digestion. I talked with the operating personnel, and found out what the plant treatment units were. Then I started to walk around the plant. When I came to the aeration tanks, I found they were empty. The operator said, "We have had so much trouble that we haven't been using the aerators very much. The sludge was bulking all the time, so we just discontinued the secondary treatment."

Then I walked along the sludge beds and they were overgrown with weeds and, obviously, hadn't been used for several months. So I asked, "Why aren't these in use?" He said, "Well, we had trouble getting the farmers to haul the digested sludge away, so we started dumping it directly into the river."

I looked at the digester and then noticed the boilers weren't in operation. I said, "Are you using the digesters now?" The operator replied: "No. A couple of months ago we started pumping from the primary tank directly to the river!"

Chairman Kraus: A number of years ago we made a study at Peoria to determine what the situation would be if we discharged all of the digested sludge to the river continuously, using all of the digesters to remove all of the B.O.D. possible. It was determined that plant efficiency would change from 92 per cent, on overall removal of B.O.D., to about 75 per cent. If you have an outlet stream that can take about 25 per cent of the B.O.D. load, this practice can be justified.

James Brower, Superintendent, Milwaukee (Wis.) Sewage Treatment Works: For the 21 years that I have been in this game I have unalterably opposed to by-passing anything to the river. We by-pass at Milwaukee. Everybody by-passes at one time or another. The excuse always is: "Dur-

ing a rain storm the sewage is so diluted." My answer to this is: "If I take a barrel of pure tap water and put a night crawler in it, would you use the water?" That water is polluted, pure and simple.

I believe any sewage plant should be built to keep out at all times, if possible, any pollution that might go into a stream, regardless of whether you feel that stream can take it or not. We have no right to pollute streams, but we do it. When we start to use "black market" pipes, and start to by-pass by shoving stuff in the river, why build sewage disposal plants?

In this country, why should we build plants that cannot handle the load in any particular community? If a plant is built for a certain capacity, at all times that plant should take its full capacity before the by-pass gates are opened, regardless of the outlet stream or lake.

Sludge Drying

Mr. Kunsch: Some years ago we had trouble with gas boilers in summertime operation. We were not set up to carry a high degree of heat in our boiler. We had to control the heat down to the point where the boiler water would not get too warm to be pumped directly into the digester heating coils. As a result, condensation accumulated in the boiler, a sort of gummy formation which collected on the heating or the water sections.

It was quite a job to heat the boiler properly. Even if operating it at 180° F. had been possible, which would have given much less condensate formation, the boiler would have had to be cut out of service a great deal to keep the water temperature down, and a great deal of gas would be wasted.

I don't know how the various plants handle this particular problem, or whether it is a problem for them. In the summertime most plants must waste a great deal of gas. That is one problem that we had and didn't overcome. I have wondered, though, whether any experimental work has been done on utilizing waste gas for the direct drying of sludge.

Sometime we would like to set up a little pilot drying bed at our plant, possibly a very shallow sand bed, or a bed with a concrete bottom with heating pipes inside the concrete, and burn all of the gas under the boiler, heating the sand or concrete slab supporting the drying sludge, and determine how much sludge could be dried in a small space.

Mr. Schlenz: Mr. W. A. Piatt, of Durham, North Carolina, at the large activated sludge plant there always had excess heat from the gas engines. The climate is relatively mild and there is generally more gas than can be used for normal purposes.

Piatt has placed pipe coils just under the sand surface of the sludge drying beds. Hot water circulates through these pipes and accelerates drying. When the sludge is discharged on the bed, initial dewatering by drainage is allowed to take place. Then the heating coils are used and the hot water circulated through the coils actually drives the moisture out of the sludge. Piatt says the process is very economical, since sufficient heat is available. If it was necessary to buy oil to make up for a gas deficiency, it wouldn't be practical.

Mr. Larsen: Are the drying beds open ones?

Mr. Schlenz: They are beds which have a corrugated glass top. They have no sides on them and the tops, or roofs, are just rain-shedders. They also make the beds look a little better. Piatt is putting this particular equipment in all of his plants now, large and small.

Mr. Martin: We tried something similar at Green Bay, only we put the heating coils in a concrete slab. We took a small area, about 11 ft. square, and we put a plank wall around it so there was an area of an even 100 sq.

ft. in it. We were in hopes that if we put the sludge on the slab in a very thin layer it would dry and curl up so it could be removed with a shovel or snow pusher. We were looking for a saving in labor in removing the sludge from the beds.

It didn't work out very well. We had no way of draining the water out. Where it is necessary to evaporate all of the water, it is a slow process. We noticed that along the sides, where the water had a chance to leak out, fair drying would occur. If 6 in. or a foot of sludge was placed on the slab, it was really a long, drawn-out drying process.

What we tried with a concrete slab wasn't very economical. Heating a sand drying bed might prove practical if the bed was constructed so that the initial drain water from the sludge could quickly drain away. At least it might help where drying beds are overloaded.

Mr. Brower: Perhaps air circulation would have improved drying if the bed was enclosed.

Mr. Martin: That is true, but in this particular case we had the bed enclosure wide open and had a nice draft through it.

Mr. Brower: If the temperature doesn't get very high, you have to raise the temperature of the air in order to get good drying. I believe gas could be used to that extent to aid evaporation. If the drying beds are open, the air temperature won't be raised sufficiently for good drying.

Mr. Schlenz: One engineer in the Pacific Northwest is thinking of using waste heat in hot water unit heaters placed in enclosed greenhouse-type drying beds, and thus creating a draft of warm air over the surface of the sludge. He figured the cost would be low and the excess plant heat could be advantageously utilized.

Mr. Martin: Racine has had that type of sludge bed heating for years.

Mr. Schlenz: How does it work?

Thomas T. Hay, Superintendent, Racine (Wis.) Sewage Treatment Works: We have a blower that is supposed to blow the air out of the covered sludge beds. There is so much heat loss we can't afford to put the heat into the beds.

Mr. Symons: No one seems to have mentioned spray drying. Plainfield, New Jersey has a spray drier that has been in operation for a number of years. All of the water is not evaporated from the sludge by the drier, however. The sludge is first treated with alum, and the concentrated solids floated and skimmed off. Sludge of 12 per cent solids, or more, is obtained. The sludge is discharged to a rotary fan-like arrangement on top of a drying tower which breaks up the sludge into fine particles. These then drop down through heated gases in the drying tower and are dried. Heat is obtained from digester gas.

Mr. Sperry: Is there enough gas to keep the dryer going all the time without buying extra gas?

Mr. Symons: Yes, I believe so, and I think you will find an article on the power involved, the heat, etc. in SEWAGE WORKS JOURNAL.*

Mr. Martin: Isn't there an explosion hazard there?

Mr. Schlenz: Somebody told me recently that there had been two fires at the Plainfield plant which burned up the vacuum filter. Plainfield did try flotation of sludge with alum to get about 12 per cent sludge solids. They found, however, that to drive off the remaining moisture cost quite a little money, and they have gone to vacuum filters to get a more concentrated sludge.

Mr. Walker: I happen to know a little about the Plainfield situation. Those were fires; they were not explosions. The sludge gets so dry it just slowly ignites. It is just a fire

* THIS JOURNAL, **19**, 5, 806 (Sept. 1947).

with a slow rate of propagation. It certainly is not an explosion.

When the sludge is discharged from the dryer more as pellets and is not dried to the powdery dry stage, but to the stage where it can barely be handled on a belt conveyor, the amount of heat required is just a small fraction of that required to drive all the moisture out and produce a powdery dry material. Also, the danger of fire is materially reduced.

L. E. Langdon, Pacific Flush Tank Co.: I do know that at Plainfield they use auxiliary fuel.

Oscar O. Egger, Wisconsin State Board of Health: If we are going to use heat to dry sludge, why not go to the method that is used for drying whey? That is, dry it under a vacuum.

Mr. Brower: Some years ago I took up this matter of vacuum drying with the Manistee Iron Works in Michigan. They make vacuum pans and related equipment. At Milwaukee we dry around 170 tons of sludge per day at the present time. Most of the sludge runs approximately 84 per cent moisture, sometimes a little lower. I found that such a tremendous outlay would be required for vacuum pans and other necessary equipment that the project was impractical.

Mr. Kunsch: There is a question that has come up on condensate traps. Fairly frequent replacement of springs is necessary, at least in the PFT type, due to corrosion. Is there any metal which could be used that would withstand corrosion of this type?

Mr. Schlenz: If there is a lot of replacement of springs, operators must be buying their springs some place else. Rock Falls, Ill. is the only plant we have had that trouble with.

Mr. Hook: I would like to ask the PFT representative if they couldn't use a plastic diaphragm instead of leather in their pressure relief valves for digester floating covers.

Mr. Langdon: We have been experimenting with several types. We have plastic diaphragms that are on test at the present time, and we may have something to announce shortly.

Toxic Industrial Wastes

Chairman Kraus: Mr. Rudgal is prepared to introduce the subject of inhibiting substances in industrial waste.

Mr. H. T. Rudgal, Superintendent, Water and Sewage Treatment, Kenosha, Wis.: The subject of toxic trade wastes is a very important one. It is also a very broad one. In the few studies I have made, the difficulty has been the lack of conclusive information about the toxicity of certain wastes.

Chromium is a good example. Someone will report that 1 p.p.m. will not affect plant operation. Someone else will say that 1 p.p.m. will interfere with plant processes. The same is true of copper wastes. Something should be done to find out why toxic wastes affect plants differently. There certainly are reasons for it.

Copper Wastes

Carl Wahlstrom, Superintendent, LaCrosse (Wis.): We don't know what is going on at our plant. A year ago February we had a decided continuing drop in gas production. We didn't add lime, believing that the digester was probably too acid. It was suggested that possibly toxic wastes might be present, because of the two large engraving plants in town.

Samples of raw sludge, sludge in the digester, and sludge drying on the beds were found to contain 12,000 to 14,000 p.p.m. of copper.

So we started to work on these engraving plants. We also had to empty our digesters, which was quite a problem. We bought diaphragm pumps and emptied the secondary digester completely. The primary digester was also emptied, except for 2 or 3 ft. of sludge.

In October we started to refill the

digesters. Sludge was pumped to the digesters only on Saturday, Sunday, and Monday because the industries do not work Saturday and Sunday. Eventually a little gas production was obtained—10,000 to 15,000 cu. ft.

In February of this year the gas production started going up. We thought the industries had reduced the amount of their wastes. Gas production went up to 70,000 cu. ft. per day, and then it dropped sharply again and went down to 20,000 cu. ft. and coasted along at that rate until about April 15th, when it started to rise.

At the present time we are averaging 60,000 cu. ft. of gas per day, which is the highest gas production in the history of the plant. The long-time plant average is about 45,000 cu. ft. per day. The population of LaCrosse is about 50,000.

By checking the industries and through the grapevine we found that at one plant there isn't enough tank space to decopperize. This plant was using iron pipe to precipitate out the copper, and they thought that rather than build additional tanks it would be cheaper to empty the waste into the sewer. We think that is what upset our digesters.

At the present time we are running analyses for copper and chrome, and find we are still getting a large amount of both. Last week the raw sewage contained 3.6 p.p.m. of copper. Maybe we have a different bug in the digesters that can live on copper.

These industries have been in operation since before the sewage plant was built and the plant has always received the wash wastes. Copper content of the sewage in sewers near these industries varies from 2 to 8 p.p.m. These quantities have been checked several times. Maybe the digesters will stand from 10,000 to 15,000 p.p.m. of copper. That is the answer I am trying to find out.

Mr. Walker: You have 10,000 to 15,000 p.p.m. of copper in the digester now?

Mr. Wahlstrom: Yes. And a high gas production.

Mr. Walker: Do you have much sulfide?

Mr. Wahlstrom: No, we don't.

Mr. Barker: You mentioned there was also chromium in the digester. How much does that run both in the raw sludge and in the digesters?

Mr. Wahlstrom: In the digesters it averages about 4,000 to 5,000 p.p.m., and about 1.5 p.p.m. in the sewage the last time.

Mr. Barker: Was it in the hexavalent or trivalent form?

Mr. Wahlstrom: We haven't determined that.

Chairman Kraus: Is any of that copper or chrome in solution in your digesters?

Mr. Wahlstrom: The last samples tested indicated 4.6 p.p.m. of copper in the raw sewage and 0.2 p.p.m., or a little better, in the plant effluent.

Chairman Kraus: Those are determinations made on total solids, are they not? Have you ever carefully filtered the material so that you can determine the ions in solution? I firmly believe it is the ions in solution that have the toxic effect.

Mr. Wahlstrom: Mr. Nichols has done this for us, but I don't have that data with me.

Mr. Rudgal: I am wondering whether Mr. Wahlstrom has actually built up a stable copper concentration and if he knows what the concentration will be as the plant operates. He may have a condition where all the copper has been precipitated in the bottom. The recent big increase in gas production may be due to fresh sludge, plus some seed, which has accumulated above the copper-containing sludge on the bottom.

It is possible to start with 1 or 2 p.p.m. of copper in the raw sewage and get 200 p.p.m.—on a wet basis—

in the wet sludge. This may accumulate to 2,000 to 3,000 p.p.m. in the digesters. Copper concentrations should be expressed in per cent, or as parts per million of dry solids.

If a sludge report shows 400 p.p.m. and the dry solids in the sludge are 4 per cent, on the dry solids basis, the copper concentration is 10,000 p.p.m. However, if the sludge is 8 per cent dry solids, the copper concentration as per dry solids is only one-half of that present in the 4 per cent sludge, or 5,000 p.p.m.

At Kenosha we found that any time the copper concentration became greater than 5,000 p.p.m., gas production per pound of volatile matter decreased.

Back in 1940 the only reports I could find on chrome and copper were those of the State Water Commission of Connecticut. In checking those data with later information I find that again there is no agreement. Some investigators report 1 p.p.m. detrimental to biologic life while others maintain that as much as 2.2 per cent can be tolerated. The Connecticut report states: "When more than one part per million of chromium is present in the sewage as received at a sewage treatment plant employing anaerobic digestion, it is desirable to install chemical treatment processes, such as were discussed above, and remove these at the source." In another place it states that a plant can take 2.2 per cent chromium without trouble. I wonder if some gentleman would care to take up some phase of it.

Chromium Wastes

William E. Ross, Richmond (Ind.), City Engineer: During the war we had an electroplating plant operating at Richmond which was supposed to be the largest in the world. There were 48 electroplaters in operation, producing a waste with a chromium content that ran as high as 30 and 40 p.p.m. at the plating plant. The volume of the waste averaged 120 g.p.m. for the full 24 hr. per day. At times the waste volume was even higher.

After a great deal of trouble in trying to find a suitable test for chromium we were able to develop a test of fair accuracy which could be standardized. About that time we also were able to stabilize plant operation to the extent that the plant could handle 0.75 p.p.m. of chrome waste in the raw sewage. The effluent was poor, but passable. Suspended solids in the effluent were high and digestion rates were low. The plant, however, was doing fairly well.

Then V-J Day came and our troubles ceased because both plants shut down immediately. Now, one is starting operation again and we are not too sure of how much chrome waste they are going to produce.

Apparently the trivalent chrome doesn't hurt anything; it is the hexavalent that is toxic and causes the trouble. If there is anything in the sewage that it can react with, it may react, and by the time it gets to the sewage plant there is no way of knowing just what the concentration is and how much effect it will have on the plant. We are fairly sure if the waste contains over 0.75 p.p.m. of hexavalent chrome, it will affect the plant adversely.

Dr. Hatfield: I am wondering if we shouldn't differentiate between the trivalent and the hexavalent chrome and the length of time it takes to react.

Recently there was an article in the JOURNAL by Edwards on the tremendous amount of chromium an activated sludge plant in New York City took without any detrimental effects. I forget whether it was 30 or 40 p.p.m., or 300 or 400 p.p.m., but it was a large amount.

We had a somewhat similar experience in Decatur during the war when we got large quantities of chrome, 10 to 12 p.p.m. We didn't find that the

activated sludge took up a great deal of the chromium. However, the chrome waste we received came in short doses. Three or four hours were required, occasionally 24 hours, before the chrome was cleaned out of the plant. Apparently the remainder of the time the chromium wasted was so low that it didn't affect the plant. One p.p.m. of chromium can be seen in normal sewage by its yellow color. You don't have to have chemical analysis. You don't know, however, whether it is trivalent or hexavalent.

For a few years we received 10 to 15 p.p.m. every 3 or 4 days, or about once a week. At that rate it did not affect us. I think the important factor is whether a small quantity is received for a long period of time, or whether a large quantity is received in a short time that doesn't last long enough to exert an appreciable toxic effect.

Mr. Ross: I think that is borne out by the Anderson, Indiana, experience. Fairly heavy doses of chrome waste were received for periods of ½ to ¾ of an hour at a time. The plant recovered from these shock loads without trouble. At Richmond we had a continuous flow of chrome waste 7 days per week. Plants seem to be able to take fairly high shock loads and recover but continuous loads of low concentration invariably cause trouble.

Mr. Schlenz: In dealing with digesters it is important to know how much of the waste concentrates in the digester. In order to analyze the Richmond problem it is necessary to know how much of the chrome passes on with the clarifier effluent and how much ultimately reaches the digester.

Mr. Mathews: We have just about reached the end of the time allotted for this forum. In spite of all the discussion that has occurred, I still haven't heard anyone answer my question: "What happens when we put 100 lb. of lime in a million-gallon digester, and why does it bring the gas production back?" Gentlemen, I shall make a special effort to be at The Operators' Breakfast next year, so that I can ask that question again!

INTERESTING EXTRACTS FROM OPERATION REPORTS

"You can't make footprints on the sands of time by sitting down!"
—*Symons*

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage Works Associations, Room 325, Illinois Bldg., Champaign, Ill.

Annual Report of the Sewage Works Manager, Borough of Slough, England, for the Year 1947–48

By M. A. Kershaw, *Manager*

Description of Plant

The main treatment works are situated at Cippenham. The plant was constructed in 1936–38, comprising detritus tanks, screens, sedimentation tanks, 12 percolating filters, humus tanks, sludge digestion tanks and sludge drying beds. In addition, the

original works, constructed in 1917, still function to a very limited extent and some 30 acres of land are also used for final treatment by irrigation.

Adjoining these artificial works and connected thereto by distributor pipe lines is the farm at Dorney, comprising some 147 acres. This area is used for the disposal of partially treated sewage, storm water, and surplus sludge by irrigation, the land areas being maintained in good condition for irrigation work by systematic cropping, etc.

The district works at Langley occupies some 25 acres of land where sewage from the eastern part of the town is dealt with by irrigation after preliminary tank and coarse filter treatment.

Flow Variation

During certain hours of each day the rate of flow of sewage into the works is very high so that it is impossible, with the present capacity of the treatment units, to deal with the volume of sewage arriving. At these times the storm water overflow comes into operation and a considerable volume of sewage is by-passed into the storm water tanks which in this way are made to function as balancing tanks, holding the excess volumes of sewage until periods of "slack" flow when it can be returned for treatment through the works.

The final effluents discharging to the river have been maintained to a reasonable degree of purification—the average percentage purification throughout the year being 87.4 per cent. This figure, which is slightly higher than last year (84.6 per cent), has already been achieved by constant attention, at all points, throughout the works; from the laboratory to the effluent discharge.

With the increasing age of the works and the steady accumulation of plant, the repair work increases and it is more and more apparent that failure to provide a suitably equipped workshop when the works were constructed in 1936 was a serious oversight.

The labor position is, if anything, worse than last year. It is impossible to offer wages and amenities such as are available in local industry so that it has not been possible to replace even the men who have retired on superannuation, let alone increase the number of men, urgently required, to bring the total to the minimum number for the proper working of the department.

Laboratory

In all, 1,485 samples were obtained and examined in the laboratory, involving 11,733 separate estimations.

The samples were made up as follows:

Routine samples for treatment control	1,092
Samples of trade waste effluents	376
Special investigations, etc.	17
	1,485

Apart from routine work special attention has again been directed to providing data for the temporary improvement of the treatment units, now operating on a considerable overload until such time as the major extensions to the work are completed.

This work has covered:

1. Investigations into the operation of shallow effluent lagoons.
2. Experiments in recirculation of the filter effluent.
3. Control of the sludge digestion tanks and the production of methane gas.
4. Long term research work, commenced last year, has been continued and developed this year in connection with the standardization of the method of determining the B.O.D. of sewage and effluents. In connection with this work, close collaboration is being maintained with other workers in this country.

Trade Waste Effluents

There has been a very considerable expansion of this work as shown by the fact that during the year under review 781 visits were made to factories and 376 samples of trade waste effluents were obtained for laboratory examination. For the year 1946–47, 423 visits of inspection were made and 131 samples obtained.

During the year, 28 factories were surveyed for the first time, bringing the total number of factories now subject to regular inspection to 109.

This large increase in inspection work produces a corresponding increase in the office routine of record keeping.

The volume of trade waste effluent reaching the works is estimated to be 450,000 gal. per day.

The wide variety of products manufactured in Slough produces an equally wide variety of trade waste effluents, each varying greatly in composition and strength as shown in Table I.

During the year many improvements have been made to pretreatment units at several factories, resulting in a more carefully "balanced" discharge and, in some cases, a reduction in the strength of the discharge.

Considerable interest has been taken throughout the country in this work and many requests have been received during the year from other local authorities for details of the methods of inspection and control as applied in Slough.

Manor Farm

The work of the farm has continued throughout the year towards completion of the committee's progressive policy or adjusting the farm land to functioning as a satisfactory treatment unit for sewage liquor and sludge, while producing, as far as possible, normal crops.

It has been possible to carry out certain work on the last portion of the farm to be "reclaimed," and it is anticipated that during the coming year this work will be completed so that the whole farm area will then be available for controlled irrigation and rotational cropping.

The primary object of the farm is as a unit of sewage disposal and during the year approximately 130,000,000 gal. of sewage and practically all the sludge has been disposed of, without nuisance, in this way. The value of rotational cropping as an aid to this work can be judged from the fact that the volume of sewage disposed of in this manner is 30,000,000 gal. or 33 per cent more than last year.

Owing to the very serious flooding of the area in March and April of 1947 the cropping program was seriously delayed. This situation, combined with an acute labor shortage, made cultivation work extremely difficult. In spite of these problems, and the additional work entailed in adjusting the work of the farm to suit the requirements of the committee's policy of increasing the areas under grass and the change over to stock rearing, very useful crops were again produced and the estimated income of £1,000 was exceeded by some £300.

During the year a further area of 12 acres was put down to grass and a similar area will be grassed in 1948–49. This will mean a further reduction in the area of land under arable cultivation, but by 1950 the change over should be completed, after which it should be possible to assess the increased benefits, already indicated, of the new system of farm operation, viz.,

1. The increased capacity of the land for sewage and sludge treatment.
2. The reduction of labor for farm work.
3. The increased production of beef.
4. The production of a valuable concentrated cattle food in the form of dried grass which should have a ready sale to dairy farmers.

TABLE I.—Analyses of Trade Wastes, April 1947–March 1948*

Type	No. of Samples	pH	Oxy. Absorbed N/80 $KMnO_4$ Lab. Temp.		Chlorions	Nitrogen				Acidity or Alkalinity as $CaCO_3$	Suspended Solids	B.O.D. 5 Days at 18.3° C.	Remarks
						Ammoniacal		Oxidized					
			(3 min.)	(4 hr.)		NH_4	NH_3	NO_2	NO_3				
Acid Wastes	44	3.4	16.8	27.2	253.0	—	—	2.23	17.3	3215.0	79.0	5.2	Cr·Fe·HF·Cu
Plating Waste	46	6.3	04.9	14.2	286.0	11.3	4.5	0.40	11.0	1113.0	200.0	11.0	Cyanides, Ni., Zn
Lead Paint	39	5.9	07.6	11.7	94.0	3.3	1.6	0.85	106.0	286.0	315.0	288.0	Total Lead as PbO-2281
Syn's., Chemicals	17	8.2	371.2	682.0	748.0	38.9	2.9	—	—	2244.0	383.0	6836.0	Solvents, Paints, Oils, Cr.
Fats, Soaps, Cos'cs	38	8.1	96.6	397.5	1441.0	14.1	6.1	—	—	1485.0	2056.0	349.0	Solvents, Soaps, Grease
Foods and Confections	45	7.0	40.5	398.0	122.0	44.1	20.9	nil	nil	291.4	621.0	2474.0	Sugars, Starches, etc.
Gas Liquor	22	8.0	5128.0	11695.0	7395.0	6670.0	1092.0	nil	nil	1553.0	184.0	5340.0	Sulfides, CNS, Phenols, etc.
Starch and Glue Pro'ts	11	6.9	102.4	1836.0	164.0	25.4	29.7	nil	nil	378.0	771.0	1778.0	Free Starch
Wallpaper Manu're	35	7.4	9.9	50.1	113.0	1.3	3.9	0.01	trace	266.0	1438.0	255.0	Cu, Zn, Ni, Cr, Starch
Rubber and Latex	15	7.3	263.0	892.0	382.0	2219.0	814.0	—	—	256.0	896.0	2486.0	Coag. Rubber
Dyeing, Bleaching Textiles	10	7.3	56.2	116.6	829.0	7.5	10.9	—	—	402.0	67.0	264.0	Free Chlorine, Sulfides
Anodizing	5	6.0	1.8	4.1	88.0	—	—	0.09	nil	62.5	22.5	—	
Surface Waters	19	8.9	6.5	18.6	158.0	1.8	0.8	0.13	nil	528.0	175.0	14.2	Fats, Oils, Bitumen, Chemicals
Others	24	—	—	—	—	—	—	—	—	—	—	—	Resin, Solvents, Paints

* Results expressed in p.p.m.

Thames Conservancy

During the year inspectors of the Thames Conservancy visited the Cippenham works on 10 occasions and the Langley works also on 10. Eleven official samples of final effluent were obtained.

The steadily increasing overload on the main works at Cippenham has made it impossible to produce, at all times, a final effluent which conforms to the required standards as laid down by the Thames Conservators. It is interesting to note, however, that due mainly to the increased volume of sewage treated on the farm and the consequent easement of the load on the artificial treatment units, it has been possible to achieve an increase in the percentage purification over the figure obtained during 1946–47.

Visitors

A large number of visitors have again been conducted over the works and farms during the year.

Among the 313 visitors there were official representatives from South Africa, India, Portugal, and Czechoslovakia.

Exhibition

For the first time the department participated in a public exhibition held in the town during February, 1948 in connection with the National Savings Campaign.

The work of the department was fully displayed and included plans; cartoons; photographs; special ranges of samples, of sewage, trade waste effluents, and final effluents. Laboratory scale experiments were operating to demonstrate various methods of sewage treatment, and a scale model of a modern sewage works was also on the stand. The activities of the farm were illustrated by samples of produce and photographs.

Although the number of visitors to the exhibition was not large, it was obvious from the keen interest taken by visitors that the work entailed in the preparation of the stand was amply justified.

A summary of operation data for the Cippenham works for the year April 1947–March 1948 is given in Table II.

TABLE II.—Summary of 1947 Operating Data, Cippenham Sewage Plant, Slough, England

Item	Average
Area of Borough (acres)	6,276
Population (estimated)	70,000
Rainfall (in.)	18.55
Average sewage flow (m.g.d. Imp.)	1.91
Per cent overload on treatment works	27.3
Total number samples examined	1,485
Individual estimates	11,733
pH:	
Raw	7.6
Settled	7.3
Humus tank effluent	7.0
Old works filter	7.4
Lagoon effluent	7.7
Oxygen absorbed (4 hr. N/80 $KMnO_4$, Lab. Temp.) (p.p.m.):	
Raw	151.5
Settled	98.2
Mixed filter effluent	31.7
Humus tank effluent	19.0
Old works filter	49.1
Lagoon effluent	38.5
Nitrogen (NH_3) (p.p.m.):	
Raw	137.1
Settled	99.5
Mixed tank effluent	24.8
Humus tank effluent	27.7
Old works filter	73.3
Lagoon effluent	72.5
Nitrogen (NO_3) (p.p.m.):	
Mixed filter effluent	19.4
Humus tank effluent	22.0
Old works filter	2.8
Lagoon effluent	0.5
Suspended solids (p.p.m.):	
Raw	748
Settled	153
Mixed filter effluent	159
Old works filter	125
Lagoon effluent	39
B.O.D. (5 days at 18.3° C.) (p.p.m.):	
Raw	560
Settled	320
Mixed filter effluent	57.0
Humus tank effluent	19
Old works filter	79
Lagoon effluent	40

Seventh Operation Report of the Sewage Treatment and Garbage Disposal Plant, Marion, Ind., for the Year 1947 *

By David Backmeyer, *Superintendent*

The revenue received from sale of liquid sludge fertilizer totaled $1,486.65. This source of revenue showed a decrease of 12.7 per cent from the total collected in 1946. Because of the extended periods of wet weather in the early spring months, it was impossible to make liquid sludge deliveries to many of the farm customers who had placed orders for the fertilizer. A check of the record of deliveries showed that 66 per cent of the total volume of liquid sludge hauled was taken to the storage lagoons, and only about one-third was actually delivered to farm fields.

Gas Production

Considerable maintenance and repair work was done on the gas engines during the year. Replacement of rod and main bearings was made on both of the 75 h.p. engines which drive the blower units. In this same month 23 per cent of the total gas produced had to be wasted due to engine repairs.

The total gas produced for the year was 23,167,300 cu. feet. This volume is about 2 per cent less than the total produced in 1946. The estimated value of the gas used (21,461,000 cu. ft.) for engine fuel and for the heating boiler is $10,730.50. Approximately 15 per cent of this total is attributed to the garbage volatile solids added to the digesters from the grinding of 1,108 tons of green garbage at the plant.

New Garage Building

The construction of a new garage building at the rear of the plant was started in October. This new building, which has a floor area of 2,300 sq. ft., will provide shelter for both garbage and sanitation department trucks. Floor slab heating is provided for this building by means of hot water circulated through copper coils laid in the concrete floor. In the past it has been the practice to waste some of the heat from the gas engine cooling jackets, and by making connections to the floor heating circuit of the garage it will be possible to recover and use all of this available source of heat for maintaining proper temperatures in the garage building. Roof trusses and steel girders used on the new building were salvaged from the old iron storage shed when it was dismantled previously.

Varying Degree of Treatment

Throughout the entire year a special effort was made to effect some savings in operation costs by altering the degree of treatment given the sewage to the prevailing stream and weather conditions. For example, during the months of March, April, May, and June the average monthly rainfall was 4.13 inches. The excessive storm water during parts of this period reduced the organic strength (B.O.D.) of the raw sewage to a rather low figure. In the month of May the average B.O.D. of the raw sewage was 127 p.p.m. Through such periods it is usually possible to produce a satisfactory effluent by using only 75 per cent of the total aeration tank capacity, which in turn permits the use of one blower unit for aeration of the activated sludge.

This year, however, the problem of reducing treatment costs by such methods was complicated by the introduction of a troublesome industrial waste into the sanitary sewers during the spring months. In several instances large volumes of cheese whey were dumped to the sewer by the local plant of Swift & Co. In each case the sew-

* For last previous extract see This Journal, **20**, 2, 328 (Mar. 1948).

age disposal plant was badly overloaded, as evidenced by the resultant poor removals of B.O.D. shown for these months. This waste is now hauled to the treatment plant in tank trucks, and used as a sluicing liquid when the garbage is ground. In a paper prepared for the Third Industrial Waste Conference at Purdue University it was shown that the organic load from the cheese whey would at times be as great as 70 per cent of the sewage load from the entire city. About 90 per cent of the solids in the whey are organic solids which are readily convertible to gas in the digestion process.

Items from the Daily Log

Two new pressure relief valves installed on gas storage tank. One valve formerly on this tank would not operate because of corroded seat. New valves set to open at 60 p.s.i.

Lights on compressor building re-set for ice skaters as colder weather makes ice safe for skating. Plant operators draw 30,000 gal. of digester liquor to primary settling tanks by error.

Sewer department crew spend a day with our men cleaning out raw sludge suction line. Line was plugging up; feathers and garbage wedged in 6-in. pipe which was partially filled with waxy coating that had accumulated during past 11 months.

Inquiry at Swift & Co. reveals this industry is dumping 40,000 lb. of liquid lactose whey to sewer 5 days a week. D.O. is still low in aerators with air volume doubled. Sludge index has jumped several more points.

Webb-like mark on crank shaft journal of gas engine is investigated by insurance inspector, as possibility of faulty shaft is suspected. Later tests show shaft to be sound. Poorly fitting rod bearings have given continuous trouble on 75 h.p. Climax engines. Replaceable bearing shells distorted in shape when mounted in rods and caps. This can be overcome by boring with vertical mill after bearings are mounted.

Aeration liquor smells like glue and final tanks are milky in appearance. Swift & Co. has again given us a present of 17,000 gal. of cheese whey in 4 days. Gas production in digesters jumps to 100,522 cu. ft. today.

Local welder mends broken comminutor basket bars on 25-in. machine when it is in shop for complete overhaul including new lower bearing.

Portable Jaeger pump driven by gasoline engine is installed for circulation of contents of primary digester as recommended by P.F.T. men.

Samples of top scum in primary digester analyzed. Top 6 in. had 33.4 per cent total solids. Sample 4 ft. down showed 16.4 per cent solids, 5 ft. down 4.46 per cent total dry solids.

Arrangements made to haul liquid cheese whey to sewage plant in tank truck. Whey will be dumped in garbage well and pumped to digester with ground garbage. Temperature of whey ranges from 90° to 140° F. and makes excellent liquid for grinding garbage.

Both pistons of plunger pump replaced by rebuilt set. Badly worn pistons will be built up and machined to proper size.

Operation records checked for comparison of sewage gas and utility gas requirements of gas engines. Purchased utility gas having 1,000 B.t.u. content is sometimes used in engines. 1,000 cu. ft. of sewage gas equivalent to 680 cu. ft. of purchased gas by actual operation records.

Brass tubes in heat exchanger are 30 months old today. We apparently have found a tube that will give prolonged service.

All 2-in. air feed lines replaced in aeration tank feed channel. Original lines were badly corroded. New galvanized pipe carefully cleaned and painted with three coats of acid-proof paint.

TABLE III.—Summary of 1947 Operating Data at Marion, Indiana

Item	Average
Rainfall (in.)	33.49
Tributary population-equivalent:	
Suspended solids (0.22 lb. per cap.)	30,300
B.O.D. (0.17 lb. per cap.)	41,200
Sewage flow (m.g.d.)	4.54
Suspended solids (p.p.m.):	
Raw	178
Settled	133
Final	12
Per cent removed	89.5
B.O.D. (p.p.m.):	
Raw	184
Settled	153
Final	13
Per cent removed	90.2
Activated sludge:	
Ratio return sludge to flow (%)	35.9
Detention in aeration tanks (hr.)	4.17
Mixed liquor suspended solids (p.p.m.)	3,368
Return sludge suspended solids (p.p.m.)	13,112
Return sludge per cent volatile	68.7
Sludge index (Mohlman)	75
Cu. ft. air per gal. raw sewage	1.03
Cu. ft. air per lb. B.O.D. removed	918
Raw sludge data:	
Dry solids (1,000 lb. per month)	238
Total solids (%)	4.50
Volatile solids (%)	67.3
Digested sludge data:	
Wet solids removed (1,000 gal. per month)	732.9
Dry solids removed (tons per month)	86.7
Total solids (%)	2.82
Volatile solids (%)	54.5
Garbage disposal:	
Green garbage hauled to plant (tons per month)	92.3
Dry garbage solids to digester (1,000 lb. per month)	32.41
Volatile solids (1,000 lb. per month)	29.02
Cheese whey to digester:	
1,000 gal. per month	45,312
1,000 lb. dry solids per month	14,833
1,000 lb. volatile solids per month	13,547
Total volatile solids to digesters (1,000 lb. per month)*	212.5
Digester gas (cu. ft. per lb. volatile solids)	9.5
Per cent from garbage solids	14.1
Cu. ft. per capita per day	2.38
Per cent CO_2 content	34.7
Treatment costs (plant operation only):	
Per million gallons ($)	24.16
Per capita for the year ($)	1.51
Per 1,000 lb. of B.O.D. removed ($)	18.04

* Includes volatile solids from sewage, garbage, and cheese whey.

Group of 22 ladies representing League of Women Voters visited the treatment plant.

New shoe plates being put on grit collector buckets. Strap iron stock welded to toe end of shoe will give good service for about 1 year.

Took motor boat trip up river to get samples of river water to check D.O. at five locations.

Dissolved oxygen of aeration tank effluent is down to zero.

Our cheese whey manufacturers gave us a 15,000-gal. sample last night despite our efforts to haul the stuff by truck. The B.O.D. population equivalent of this batch is estimated at 23,000.

Our entire stock of machine bolts and cap screws are now zinc electroplated. The cost is 5 cents per pound, a good investment for insurance against corrosion.

New oil leak detector purchased for checking bearing leaks in Climax engine No. 4. Oil pressure has been low on this engine for some time. Oil pressure is being lost in front camshaft bearing which is spurting ¼-in. stream into crankcase.

Neoprene ¾-in. packing is ordered for plunger pump. We have tried them all but this seems to be the packing for this pump.

Annual Christmas party is held at plant. Not much of the 12-lb. turkey left after twelve of us satisfy our appetites.

Operation data for the year are summarized in Table III.

Sixteenth Annual Report of the Division of Sewage Disposal, Toledo, Ohio, for 1947 *

By A. H. Niles, *Engineer-Superintendent*

Gas Engines

The two Rathbun-Jones gas engines installed in 1936 continue to perform in a very satisfactory manner. The 4-cylinder engine driving the 36-m.g.d. sewage pump was set on block cork under the large concrete base. In the 11 years of operation this cork gradually compressed to the point where the crankshaft of the engine and shaft of the pump were about $\frac{5}{16}$ in. out of alignment.

Beginning in October, this engine was completely dismantled, taken off the base, the old grouting entirely removed and the engine re-set and re-grouted with the proper alignment. The engine was down a total of 774 hours in October and November. This, of course, included the annual complete overhaul, but represents the longest "out of service" experienced for several years.

The total savings of the two gas engines in the 11-year period since installation now amounts to $152,379.63. The gas engine installation originally cost $41,075 in 1936.

Tol-E-Gro

For several years it has been planned to paint the glass-covered sludge drying beds, but for one reason or another this was delayed until last summer. Then at a cost of about $11,000 for labor and material, a contract was let for this work. Due to the fact that the inside of the superstructure could be painted only when the beds were entirely empty, a great deal of sludge drying time was lost. This was reflected in the smaller sludge-fertilizer production and sales in 1947 and will show smaller tonnage sales in 1948.

The dollar sales of Tol-E-Gro should hold up well in 1948 because of a price increase as of January 1, 1948, but the amount of Tol-E-Gro in storage for the spring of 1948 was the lowest it has ever been. Processing costs per ton since 1942 are as follows:

1942	$2.99 per ton
1943	3.30 per ton
1944	3.94 per ton
1945	4.06 per ton
1946	4.13 per ton
1947	4.31 per ton

Recommendations

For several years the writer has been considering the advisability of recommending that the city initiate a bureau for testing the materials which are furnished by various venders. This has never been done in a city laboratory and only in a piecemeal spasmodic manner by private testing laboratories. During and just after the war there was such a scarcity of material that it did not seem feasible to recommend it. However, materials are now tending to be in more normal supply and this seems to be a more propitious time to put the idea forth. This division has a well equipped chemical laboratory and the necessary room to install the various pieces of testing equipment to do the physical testing except for tests now being made at the Toledo Testing Laboratory. It is recommended that the laboratory continue to perform such tests as are now being handled by it and that this division be expanded to include the testing of the ordinary supplies bought regularly by the city, such as gasoline, lubricating oils, paints, cleaning supplies, electric light bulbs, and such other materials, and assisting such other divisions by laboratory analyses as may be deemed advisable.

* For last previous extract see This Journal, **19**, 280 (Mar. 1947).

This is not an entirely new precedent since this division has made some tests in the past on special occasions, particularly for the Fire Prevention Bureau, but has never had the personnel to do such work regularly nor in the amount requested.

It is recommended that a special assistant to the chemist be employed to do the testing under the direct supervision of the chemist and the undersigned. This assistant would also receive training in sewage laboratory work to the end that he would be available to take over the duties of the chemist whenever that may become necessary. The cost of operating this bureau would be negligible outside of the assistant's salary and the initial modest expenditure for equipment.

A summary of plant operation data is given in Table IV.

TABLE IV.—Summary of Operation of the Toledo (Ohio) Sewage Treatment Plant for 1947

Item	Average	Item	Average
Rainfall (in.)	36.50	To drying beds	11,440
Design flow (m.g.d.):		Tons dry sludge pulverized for fertilizer	915
Mean D.W.F.	80.0	Tons fertilizer sold	950
Max. D.W.F.	140.0	Total sales ($)	9,525
Raw sewage flow (m.g.d.)	46.3	Bay View pumping station costs ($ per m.g.):	
Screenings (cu. yd. per month)	204	Purchased power	0.30
Grit removed (cu. yd. per month)	73	Supplies	0.33
Suspended solids (p.p.m.):		Supervision and labor	3.38
Raw sewage	199	Total	4.01
Plant effluent	96	Sewage works costs ($ per m.g.):	
Per cent removal	51.4	Power	0.008
B.O.D. (p.p.m.):		Supplies	1.15
Raw sewage	205	Supervision and labor	5.86
Plant effluent	96	Total	7.02
Per cent removal	34.4	Gas engine economy ($):	
Per cent volatile solids:		Pumping cost if power purchased	23,638.49
Raw sewage	65.4	Actual pumping cost	6,058.91
Digested sludge	44.4	Gas engine saving	17,579.58
Digested sludge (cu. yd.):			
To marsh	30,525		

DISPOSAL OF CHEESE WHEY BY DIGESTION

By David Backmeyer

Superintendent, Water and Sewage Treatment Utilities, Marion, Ind.

The sewage treatment and garbage disposal plant at Marion, Indiana, was completed and placed in operation in July, 1940. This plant, which utilizes activated sludge for secondary treatment, is equipped with complete facilities for separate sludge digestion of both sewage and garbage solids, together with gas engines for utilization of the digestion gas. The resident population of Marion in 1940 was 26,676. The total gas production in 1947 was 23.167 million cu. ft., which is the equivalent of 2.37 cu. ft. per capita per day.

Whey Waste Problem

During the past 3 years the sewage plant has been seriously overloaded during the spring months of each year from cheese whey discharged to the sanitary sewer by one of the local milk processing plants. As the treatment plant had been disposing of digested sludge in liquid form by hauling in tank trucks (Figure 1), the facilities of

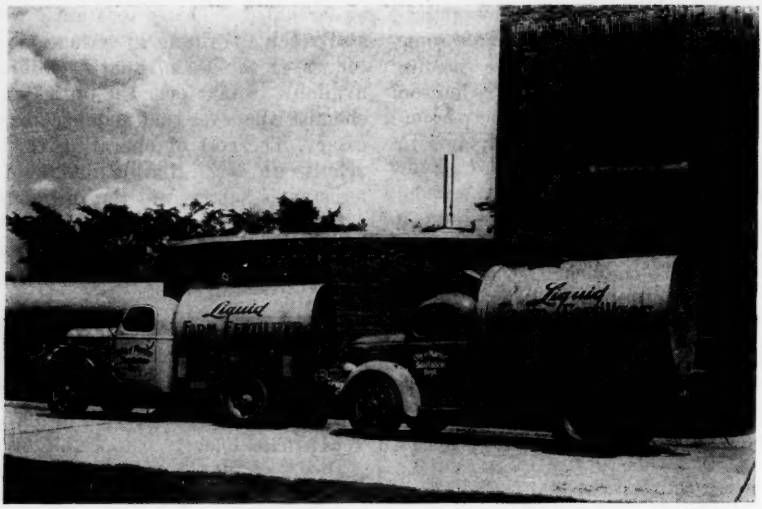

FIGURE 1.—Liquid fertilizer tank trucks used for hauling whey to sewage plant.

the sludge disposal plant were offered to the industry in an effort to completely eliminate the discharge of the whey to the sewer.

In March, 1947, arrangements were made with the industry to haul the whey from their storage tank directly to the sewage treatment plant in city tank trucks. The whey is unloaded at the plant directly into the garbage well from which it is pumped to the sludge digestion units. In this way the soluble B.O.D. load does not mix with the raw sewage flow and cannot, therefore, reach the activated sludge secondary treatment units.

Whey Mixed With Garbage

In the processing of the garbage at the treatment plant, the green garbage is unloaded from the collection trucks onto an open platform at grade level, and is then shoveled into the hammermill grinder hopper. Sluicing water is added in the grinding process to bring the final slop to a solids content of from 5.0 to 7.5 per cent, on dry solids basis.

After some experimentation it was found that the liquid cheese whey made an ideal substitute for the sluicing water. The temperature of the whey was always from 100° to 140° F. when unloaded from the tank trucks. This warm liquid would serve as a tempering agent when added to the garbage being ground, particularly in the cold months of November and December. Instead of pumping garbage slop to the digesters at 55° F., it was possible to maintain the temperature of this mixture of ground garbage and whey at 90° to 95° F. by unloading the whey tank truck as the garbage was fed to the grinder.

Whey Increases Gas Production

Cheese whey contains from 4.5 to 7.0 per cent total dry solids, and only about 8 or 9 per cent of the solids is inorganic ash. The other constituents, sugar, protein and fat, are readily digestible and are easily converted into gas in the sludge digesters. By substituting whey for water in the garbage grinding process it was further possible to recover valuable gas from the whey without overloading the plant digesters from the standpoint of liquid

TABLE I.—Effect of Whey on Plant Operation

	Plant Operation Data Before and During Whey Discharge to Sewers				
	Batch Discharge of Whey to Sewers, June 23 to July 7, 1946	Continuous Discharge of Whey to Sewers		Average for 1946	Average for 76 Months Prior to Jan. 1, 1947
		Feb. 18 to Mar. 12, 1947	May 18 to 30, 1948		
B.O.D. (p.p.m.):					
Raw	232	212	219	174	188
Settled	162	182	149	152	134
Final	7	31	29	13	13
% Reduction	96.8	85.4	86.7	92.8	93.4
Sludge Index (Mohlman)	138	118	107	91	81
D. O. Aerator Effluent (p.p.m.)	1.8	0.9	0.8	3.1	—
Activated Sludge Volatile Solids (%)	65	75.7	68.4	61.5	58.9
Air Supplied, Cu. Ft./Gal. Sewage	1.04	1.06	1.32	0.90	0.89

volume fed daily into the digestion system.

A sharp rise in the gas production rate was evident within 30 minutes after the garbage-whey mixture was pumped to the digesters. On several days when peak loads of whey were handled it was necessary to pump the pure whey to the digesters without the addition of ground garbage. Gas production volumes on these days soared to as much as 108,000 cu. ft. per 24-hour period.

Although the addition of whey to the already heavily loaded digestion system made it extremely difficult to withdraw clear supernatant from the digesters, at no time was there any evidence of foaming or excessive volatile acid accumulation in the digestion system. The carbon dioxide content of the gas produced would increase from 33.0 per cent when small volumes of whey were being handled to about 36 per cent when large volumes were taken and gas production was at its peak. No difficulty was encountered in using this fuel in the plant gas engines.

Effect of Whey on Plant Operation

Two tables of plant operation data are presented. Table I shows the effect of the whey on the activated sludge units when it is dumped to the city sanitary sewers. When whey reaches the aerators a series of rapid changes takes place. The color of the activated sludge will change in a 12-hour period from chocolate brown to slate gray. The volatile content of the sludge rises rapidly within a period of 6 to 10 days. It is almost physically impossible to supply enough air to maintain dissolved oxygen in the mixed liquor. Septic conditions, of course, lead to black sludge and the complete loss of the active sludge if part of the load is not diverted by by-passing after primary treatment.

The plant effluent becomes murky and B.O.D. reduction drops sharply. The sludge index rises rapidly and within several days, if the overload continues, a reduction in flow volume to the final tanks must be made.

TABLE II.—Whey Discharged to Digesters During 1947–48

Month	Loads	Thousand Gallons	Per Cent Dry Solids	Thousand Pounds Dry Solids	Per Cent Volatile Solids	Thousand Pounds Volatile Solids	Thousand Pounds Sludge Dry Solids, to Plant	Percentage Whey Solids of Sludge Solids	B.O.D. of Whey (p.p.m.)
1947									
March	23	29.7	5.60	14.2	92.0	13.1	223.1	6.35	—
April	27	36.9	5.74	17.8	91.5	16.3	113.6	15.70	—
May	43	43.0	6.31	23.0	91.7	21.1	205.5	11.20	—
July	34	34.0	6.03	17.0	91.5	15.5	288.6	5.89	—
August	25	25.0	5.50	11.5	91.0	10.4	292.3	3.92	33,100
September	2	2.0	6.48	1.1	94.5	1.0	276.8	0.39	46,200
October	61	61.0	5.65	28.8	92.5	26.6	236.2	12.16	36,300
November	73	73.0	5.19	31.3	90.9	28.4	176.7	17.70	34,700
December	103	103.0	5.13	43.9	91.1	40.0	277.6	15.85	33,200
1948									
March	76	76.0	4.73	26.2	89.4	23.4	275.5	9.53	34,700
April	88	88.0	4.90	14.5	91.1	13.2	259.1	5.57	32,340
May	10	10.0	6.14	4.6	95.4	4.4	253.8	1.83	—
Average	47	48.5	5.61	19.5	91.7	17.8	239.0	8.80	35,700

Shock loads resulting from dumping of batches of whey to the sewers may result in an immediate overload on the plant as high as 60 to 70 per cent above the normal load. If these loads were to be treated successfully, the operator needs three additional treatment plants as stand-by units to handle them. The solution to the problem is to completely eliminate the dumping of any whey to the sewer.

Digester Organic Loads

Table II is presented to show the volume and extent of the organic load contributed by the whey waste to the digesters during several months of 1947 and 1948. In the third column from the right the pounds of normal dry sludge solids removed from sewage are shown so that a comparison can be made indicating the extent of the dry solids load which resulted from the handling of the whey. During the peak month of November, 1947, the volatile organic load from whey was greater than the equivalent load from all the garbage ground and added to the digesters.

Whey Disposal Charge

A charge of $1.00 was assessed for each 500 gal. of whey hauled from the dairy plant. The B.O.D. strength varied from 18,000 p.p.m. to 46,000 p.p.m. as shown in the right hand column of Table II. The net cost to the industry was, therefore, $6.50 to $13.00 per 1,000 lb. of B.O.D. removed, depending upon the concentration of the product hauled. The wide variation in solids content and B.O.D. was due to the fact that some of the whey was acid treated at the milk plant to remove the casein, and not all of the liquid hauled was whole whey.

Summary

This method of final disposal of cheese whey has been satisfactory from the standpoint of accomplishing a temporary solution to a difficult industrial waste problem. Utilization of the cheese whey by the dairy industry is certainly a more logical solution. The industry may then expect to realize some net revenue from the product, and the sewage treatment plant will not have to expend money for special treatment of a waste that is extremely high in B.O.D.

CLEANING A SEWER CLOGGED BY INDUSTRIAL WASTE*

By George W. Olson

City Engineer, Woburn, Mass.

The sewer which is to be discussed is approximately 4 miles long running from its connection with the North Metropolitan Relief Sewer to a point in North Woburn, Mass. It has about 1 mile of 30-in. pipe, 2 miles of 24-in. pipe, and 1 mile of 20-in. pipe; this comprises the main trunk sewer. There are also several laterals of varying sizes connected along the run of the sewer.

The main trunk sewer is built in very swampy territory on the banks of the Aberjona River, running by a pond, called Mishawun Pond, which is a shallow pond but fairly large in area. The sewer also runs by two cranberry bogs and a reservoir supplying water to these cranberry bogs.

Construction of the sewer was completed in 1935. In 1930 the sewer was originally planned to be a segment block sewer. It was constructed in 1930 from the North Metropolitan Relief Sewer, a distance of approximately 2 miles in a northerly direction. However, at the completion of this construction it was found that the infiltration of water was so great that the Metropolitan Sewer Commission refused a connection, so this length was relined with clay pipe, and there was an additional 2 miles added to the sewer.

Industrial Connections

There are several contributors to this sewer. Only the two main contributors will be considered. The first, the Riley Tannery, has a conventional settling chamber connected to the 24-in. section of the trunk sewer. This connection is made at nearly right angles, and will be referred to again later. This factory is on a lime process of tanning and the customary tannery wastes are delivered to the sewer.

The second main contributor, and the largest, is the Consolidated Chemical Industries, Inc. The effluent from this industry runs into a settling chamber, then to a grease house, then to a storage lagoon, and thence directly to the sewer. The method of connection has been changed and a gatehouse has been located on the line between the storage lagoon and the 20-in. intercepting sewer. The grease house is used to collect grease from the effluent. The waste from this industry consists of water, lime, chlorine, and grease.

As previously mentioned there are other manufacturers connected to the sewer, but the amount they discharge is negligible. There are also a few domestic connections and all connections combined contribute grease, chrome wastes, feathers and other solids.

Previous Condition of Sewer

Prior to 1947 this sewer was in a very bad condition. There were several manholes overflowing almost constantly and others were surcharged to varying degrees. It was discovered later, during a cleaning process, that the pipe was coated with at least an 8-in. coat of grease and lime on the perimeter of the pipe. It was also discovered during various cleaning operations that there were a number of objects present in the pipe. Some of these objects were: two 40-quart milk cans, rubber gloves, etc. There was

* Presented at the Spring Meeting, New England Sewage Works Association, Marlborough, Mass., May 12, 1948.

also a 12-in. pulley and shaft, several sides of leather, 4 × 4 timbers, gravel and stones.

The gravel and stones came from the connection to the Riley Tannery. At one time this connection was bulkheaded off with planks and gravel, and then construction was started on the opposite side of the tracks. But a very wet season set in and the bulkhead gave way, and all the gravel and stones supporting it washed down into the trunk sewer. This happened about 10 years ago and the gravel and stone have been in the sewer ever since.

Early Cleaning Efforts

In 1938 an attempt was made to prevent the overflow of the sewer manholes by raising them 2 feet or more, thereby increasing the hydraulic gradient. This did not prove successful because after the manholes were raised the most important part was overlooked—the sewer was not cleaned.

What little cleaning this sewer received prior to 1947 was done only in sections and only when manhole overflow occurred. A cleaning crew would clean one or two sections immediately downstream from the overflow. This would momentarily stop such overflow, and then the cleaning crew would do no more. The equipment which was used was entirely inadequate. Small brushes were pulled through the sewer with ropes by hand power, and to the writer's knowledge the entire length of the sewer was never cleaned from end to end even with this equipment. Furthermore, the manufacturers were inclined not to give the city much cooperation, and also, the city was at fault for not properly inspecting industry effluents to determine the amount of solids present, methods of screening used, etc.

New Cleaning Equipment

During the latter part of 1946 and the early part of 1947 after considerable agitation by the State Department of Public Health, the city of Woburn took over the supervision of cleaning the sewer. The first step was to purchase new equipment. This equipment consisted of one 10- to 26-in. adjustable scraper. It is a scraper which when pulled in one direction will expand to whatever size it has been adjusted, and when pulled back in the opposite direction on a tail cable it will collapse, thereby making it very nearly impossible to have this scraper stick in the sewer. Also purchased were: an 18-in. and a 24-in. turbine wire-bristled brush, some ⅜-in., 6 by 19 plow steel cables, two 5-ton hand winches, and two stands on which to mount the winches.

Construction of a gravel access road was also started. Formerly there were only a few places at which the sewer could be reached by the maintenance trucks. At some sections it was not even posible to reach manholes by foot during a wet season of the year.

Novel Float Developed

One of the most important pieces of equipment used, which purposely has not been mentioned until now, is a plain and simple beer bottle. Attempts were made to use standard methods to bring down a line from one manhole to another. Due to the surcharged condition of this sewer, floats would not move because of the great buoyancy present. The float would be pressed up hard against the top or the side of the sewer pipes which were coated with grease. The float would immerse itself in this grease and could not move. Flexible rods were also tried but it was found, due possibly to some chemical reaction of the sewerage flowing into the pipe, that the rods became brittle.

Various other methods were tried to get a float through the sewer and none seemed to work. Due to the surcharged condition of the sewer it was not possible to get down into the manhole to push anything through.

Our cleaning crew is set up with four men which proves entirely adequate. One of the laborers on the cleaning crew thought it might be wise to use an empty bottle. The writer developed this thought a little further and used a bottle partially filled with water so that it could be submerged by lowering its buoyancy. This proved very successful and where previously several days had been spent on some sections trying to get a float through, it was now possible to do this in 1 or 2 hours.

Cleaning Procedure

Sewer cleaning procedure is as follows. The famous beer bottle is floated down sewer, carrying behind it mason's twine. When the bottle appears at the next manhole downstream it is removed from the mason's twine and a length of clothes line is attached to the twine. This is pulled upstream until the end of the clothes line appears in the upstream manhole. The mason's twine is then detached from the clothes line and a ⅜-in. cable is attached to the clothes line at the downstream manhole. This is pulled upstream until the end of the cable appears at the upstream manhole. To the cable is attached an adjustable scraper, set at a predetermined size, and a "tail" cable is fastened to the end of the scraper.

The stands are set over both manholes, upper and lower, and winches are placed on the stands. The cleaning crew then goes down to the lower manhole and pulls the scraper downstream. When the scraper has come through it is removed from between the cables and the two cables are clamped together. The upper winch then goes into service and pulls the cables back upstream. A turbine wire-bristled brush is then inserted between the cables and pulled downstream. So far it has been impossible to pull the 24-in. brush through this sewer, with the exception of a very few sections.

The cleaning operation was started at the junction of the 24-in. pipe with the 30-in. pipe, and the work proceeded upstream from there. It would have been more satisfactory if it had been possible to start at the top end of the trunk sewer and proceeded downstream, but this was impossible because the sewer was so dirty that by the time one or two sections would have been cleaned the next sections below the cleaning operation would have been so full of feathers, grease, and other solids that it would have been impossible to get anything through to the next manhole downstream.

In cleaning upstream it was not practical to catch any of the solids which were loosened in the pipes because of the surcharged condition of the sewer. Any method which could have been used to prevent these loosened solids from going down into the lower sections would have backed up the manholes so the manhole being used would soon have been overflowing with sewage and solids. Therefore, it was thought advisable to allow these solids to flow away insofar as they were able to. Of course, failure to trap and remove these solids resulted in a few more trips up and down the sewer. This cleaning procedure delivered solids to the North Metropolitan Relief Sewer in very large quantities due to the large amount in the trunk sewer. As a matter of fact, the chief engineer of the Metropolitan Sewer Commission stated that so much solids and sludge reached their sewer that it was partly responsible for restricting the flow in the sewer as far as Wedgemere, which is approximately 4 miles farther down the North Metropolitan Relief sewer. The loosened solids also plugged a regulating chamber on the North Metropolitan Relief sewer.

Cleaning Difficulties.

Cleaning operations were continued up to December, 1947, and then the

snow set in, and it seemed that Woburn had at least a foot more snow than surrounding communities. It was necessary to suspend the cleaning work due to the heavy snowfall which closed the access road to the sewer. The city has as good snow fighting equipment as any city in the state, but the extremely heavy snowfall made it impossible to continue cleaning operations.

In the month of February one manhole started to overflow. The sewer runs underneath a brook called Hall's Brook. The manhole which was overflowing is situated directly on the bank of this brook, and the waste coming from the manhole flowed into the brook. This fact was pointed out by the State Department of Public Health, and immediate efforts were made to reach and clean these sections. Then the snow started to disappear, and it was possible to reach more sections nearer the overflowing manhole, so that by the middle of March the overflow had been stopped. Since then there has been no further overflow from the sewer.

The overflow which occurred during February was caused by the presence of large amounts of sludge in the sewer just below the Consolidated Chemical Industries property. This sludge came from the lagoon of the company. Before a new gate house was completed the velocity of flow from the lagoon to the sewer was sufficient to carry a good portion of the sludge into the sewer. This sludge is still being encountered.

Future Plans

In the future preventative measures will be taken to eliminate as far as possible the overflow of wastes from the sewer. Among these preventative measures is the construction of control devices by the manufacturers to even out flows occurring at peak loading periods. Others will be: better methods of settling wastes before the effluent has reached the sewer; more careful city inspection; and repair of manholes to eliminate infiltration of surface water.

As mentioned before, the Riley Tannery connection enters the trunk sewer very nearly at right angles. This connection will be changed so that the waste enters the trunk sewer more nearly parallel to the flow in the sewer.

The city plans to raise the sewer rates in order to pay for the maintenance and cleaning of the sewer. In previous years the city collected only about $5,000 to $6,000 per year in sewer taxes. For the next few years the expense of cleaning this sewer will approximate $15,000 per year so it is only fair that the manufacturers pay at least enough to cover the cost of maintenance and repair of the sewer.

GAS LINE CLOGGED BY CORROSION DEPOSIT

By William L. Edwards

Senior Plant Operator, Gowanda State Hospital, Helmuth, N. Y.

Recently at the Gowanda State Hospital sewage treatment plant trouble was experienced with the water seals on the digester gas domes blowing every time raw sludge was pumped to the digesters from the primary settling tanks. This condition gradually became worse and soon water was blown out of the seals every time they were filled, whether sludge was being pumped or not. At first it was suspected that foaming might be taking place, but tests of the scum, supernatant liquor and the digested sludge indicated a pH of over 7.0, so this theory was abandoned.

The gas dome lids were then removed and the scum lines were backflushed. The accumulation of scum inside the gas domes also was removed. After replacing the gas dome lids and securing them, the same condition continued. The drip traps on the gas lines at both ends of the tunnel were removed and found reasonably free of any accumulation. A search for a water block in the tunnel gas piping was made but without success.

Upon inspection of the waste gas burner the gas line leading from the burner to the condensate trap was found to be filled with black soot. This was thought to be the trouble so the pipe was taken apart in the tunnel and flushed with water. No relief was obtained; the seals still were spouting water into the air.

The next procedure tried was to change the relief pressure on the relief chamber of the flame trap. This also failed to do any good. The possibility of a water block in the vicinity of the flame trap was explored and all the gas

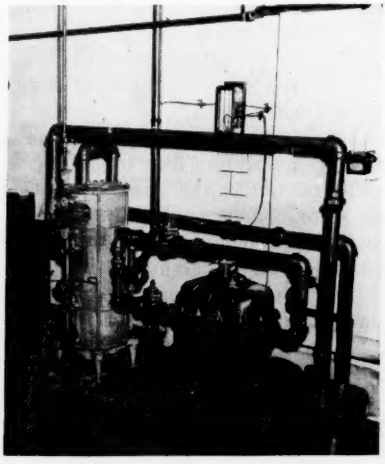

FIGURE 1.—Gas piping and flame trap installation. Corrosion deposit blocked gas line at lower elbow at left of flame trap.

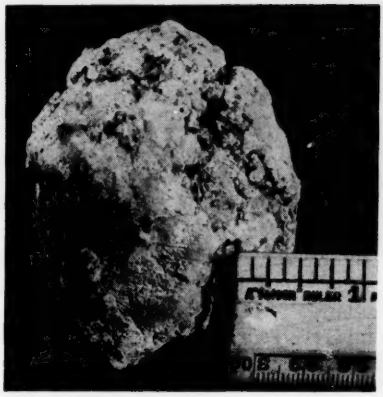

FIGURE 2.—Deposit removed from waste gas line elbow adjacent to flame trap.

piping was removed from the tunnel and around the gas meter and checked thoroughly. No water block was found. Water still bubbled out of the digester gas dome seals and also was noticed to be running from the top glass on the flame trap.

Finally, and as a last resort, the piping which supplies gas to the waste burner was removed from the discharge side of the flame trap (Figure 1), and in the 2¼-in. elbow immediately next to the flame trap a solid block of iron sediment was found. This accumulation probably had been caused by water and corrosion. It appeared to be cemented in place by black sludge.

This deposit was 2¼-in. in diameter (Figure 2) and was as hard as a chunk of iron ore. After removing the deposit and cleaning out and replacing the pipe, there was no further blowing of gas dome seals nor of water running from the top of the flame trap. Gas now freely flows to the boiler and waste gas burner. Once in a great while the seals at the gas dome still blow but this is attributed to the fact that the sludge pumps occasionally lose prime and air gets into the lines.

TIPS AND QUIPS

Visitor Dividends

The remarks expressed in the editorialette of the May, 1948, Operator's Corner concerning the value of plant visitors struck a responsive chord in the experience of at least one reader. M. A. Kershaw, manager, sewage purification department, Slough, Bucks, England, wrote concerning the dividends received from encouraging plant visitation. Undoubtedly they are representative of what other English sewage works men could report. For that reason we pass them along for your confirmation or testing.

"I would also like to fully endorse the comments expressed . . . on the question of visitors. We, in Slough, have endeavoured, during the past few years, to encourage visitors to the works and we have achieved some success in this direction. The steady stream of visitors now coming to the works produces several beneficial results, viz.:

1. The staff appreciate the attention paid to their work by outside people and they thus become more interested in their job.
2. Without unnecessary pressure the treatment units and works are always maintained to a high degree of neatness, cleanliness, and efficiency.
3. Parties of ratepayers, visiting the Department, become appreciative of the work carried out, on their behalf, by the local authority.
4. Our Lecture Demonstrations on the works and at schools provide a valuable addition to the educational work of Technical Schools and Training centers.

From the foregoing you will see that the little extra work involved, in arranging for visitors to look over the department, is amply repaid and I should like to congratulate you on the steps you are taking to develop this part of our work through your JOURNAL."

That Mr. Kershaw speaks from experience is amply indicated by the large number of visitors which view his plant each year. In 1947, 313 visitors registered at the plant. A group of visitors especially appreciated by Mr. Kershaw and his staff was the Mayor and several councilmen, who visited the plant on Christmas. The thoughtfulness and goodwill expressed by this visit will be understood by all sewage works men.

Man of the Year!

At least one sewage works personality has been making the headlines this past summer and fall. Ralph Hoot, versatile superintendent of the Fort Wayne sewage treatment works, has been spearheading in outstanding fashion a campaign for hay fever relief measures in his home town. A local columnist has nominated him as Man of the Year for "the terrific job he is doing in informing the public about hay fever, rag weed, and pollen."

A city-wide telephone poll is only one of the devices used by Hoot and his associates in enlisting public approval and support of the Hay Fever-Fort Wayne operation. A concerted publicity drive netted more than 216 in. of column space in the local dailies during 1 week.

Hoot is crusading on the premise that air pollution, like other forms, should be under the control of local and state boards of health. There's considerable logic in this assumption, and in Hoot's leadership of this project. Sewage pollution may not make a man sneeze but it will cause a taxpayer to turn up his nose—and demand relief.

And who understands better than a sewage works superintendent the sensitivity of the community nose?

An Item for the Notebook

Harry E. Jordan, secretary of the American Water Works Association, has sent us an interesting account of

sewage lift station trouble caused by pipe relining compound discharged to the sewers. The story is this.

The city of Newark, N. J., contracted for the relining of several water mains. The method used for this work was the Eric process, which consists of relining a water pipe in place with asphalt. Emulsified asphalt is poured into the pipe and then is led to deposit itself along the inside of the pipe through the use of direct current.

The Eric process has been used for several years in England and only recently has been introduced in this country. Apparently, as a pipe relining method the process proved satisfactory at Newark. While working on a 20-in. water main, however, a relining crew foreman used a near-by sewer to get rid of a considerable amount of waste or surplus lining material. The asphalt mixture passed through the sewers but collected and hardened on the screens of a sewage lift station. The use of a stream jet was required to remove the material. Extra and overtime labor used in the cleaning operation cost the city an estimated $330.

Sewage works operators would do well to make certain that any water main relining contractors working in their municipality do not use the sewers as a dumping place for waste or surplus lining material.

Sewage Pollution—and the House of Lords

Surely sewage treatment and pollution control have come of age. Or is it the world that has grown up? Now, even England's august House of Lords engages in gifted—and at times heated—debate about the perennial pollution of English waters.

Seldom, if ever, has the prosaic subject of sewage pollution received such a high-class language treatment as that administered by Lord Saltoun during a House of Lords debate on this topic last Spring. Said Lord Saltoun, in part: ". . . if another Milton were seeking for undrinkable waters to embellish his hell, he could do no better than borrow the rivers of England, which are stolen at their birth, from the cradle, to afford a scanty urban supply lest a thirsty people should stoop to drink from their feet and perish."

While some of the Lords were figuring out the above, the debate grew more intense. Most earnest of the participants was one, Lord Quibbell, who with richness of expression related a recent holiday experience in which he had dived—and stuck—in a mill stream containing 6 ft. of sewage solids. And guess who was a member of the local authority whose responsibility it was to prevent pollution in that area!

If only more public officials would go diving!

Preventing Filter Icing

With the cold blasts of winter just around the corner, many sewage works operators will be plagued again this winter with trickling filter problems caused by excessive ice formation. Sub-zero temperatures make continuous filter operation a real task, especially when the filter occupies an exposed location.

Leland Bradney, sewage works superintendent of Sioux Falls, S. D., battled the filter icing problem for years before developing a practical means for its solution. As reported in *The Clarifier*, quarterly publication of the South Dakota Water and Sewage Works Conference, Mr. Bradney's experience convinced him that filter icing was due primarily to wind action during freezing temperatures. Acting on this belief Bradney constructed a 9-ft. plank wall completely around the filter units. Experience last winter conclusively proved the effectiveness of the

windbreak in reducing ice formation on the filters.

Although the cost of such a windbreak admittedly is high, there are sewage works where the cost can be justified because of outlet stream requirements. Careful design of the windbreak would permit easy erection and dismantling. If adequately painted and properly stored when not in use, the windbreak should furnish many years of filter protection.

A View with a Sewage Works

An artist, of all people, should know what he wants in the way of atmosphere and a view. So there should be no head shaking when the word gets around of the Marion, Ind. artist who is building a studio on a site adjacent to David Backmeyer's sewage treatment works. The studio will overlook the river and the front yard of the Marion plant.

Of course some artists are crazy, but everyone who has visited the Marion plant will heartily agree that Backmeyer's artist neighbor is sound of mind. Sewage works operators will appreciate the compliment that has been paid to Backmeyer and his staff.

New Weapon for Fighting Filter Flies

Development of a powerful new insecticide that is 10 times more effective than DDT on a wide range of insects was recently announced by its manufacturer, Process Chemical & Coatings Corp., 33 N. 1st St., Brooklyn 11, N. Y.

Called CD–68, the new chemical compound contains Technical Chlordane, supposedly an unsurpassed killer of moths, mosquitoes, flies, and other household, industrial, and farm pests. This new insecticide is reported to be less toxic to humans and warm-blooded animals than DDT.

The spray application of CD–68 combines quick knock-down with killing power. This is a significant improvement over DDT, which is deficient in this respect. The manufacturer claims a residual killing potency of 5 to 8 weeks for the new insecticide. CD–68 is now available with either an oil base or a non-inflammable water emulsion.

If CD–68 proves to be 10 times more effective than DDT on trickling filter flies, its market in the sewage works field is assured. Whether the factor of comparable effectiveness is 10 or 1/10, however, remains to be determined. The knock-down properties of the new compound, if as potent as claimed, would make it a welcome weapon against filter flies even if residual toxic qualities are no greater than those of DDT.

Perhaps next summer a few billion heartless filter flies will drive several sewage works men to experimenting with CD–68. If so, we hope these "researchers" will make their observations speedily known to their brother operators through the pages of *The Corner*.

Effective Sewage Works Publicity

An excellent example of an effective public relations tool came to our attention recently in the form of a four-page descriptive folder on the Jackson (Mich.) sewage treatment plant, which was prepared by A. B. Cameron, superintendent.

The first page contains an attractive air photograph of the plant, under which is printed this friendly greeting: "We are glad you are here and you are free to go anywhere on the plant site and inspect your sewage treament plant."

Pages 2 and 3 are devoted to an understandable description, phrased in simple words, of what the plant does and how it accomplishes its purpose. We liked particularly these portions and we believe the visitors do too.

"Our job is to treat Jackson's 'used water' for a decent return to the Grand River.

"The Grand River has been greatly improved in appearance since the plant has been built and you will now find fish, plant life and other aquatic growths in the river. The use and beauty of the Grand River will be preserved and no injustice will be done to those who have equal rights down stream as long as the plant is in operation.

"The grounds, which consist of 55 acres, have been landscaped with approximately 10,000 shrubs and 1,500 trees. A soft ball diamond, picnic tables and charcoal grills have been installed for the use of the general public and are being used extensively during the summer months. Also, on the lagoons you will find a flock of mallard ducks which are making their home there. During the winter months there is skating on these lagoons.

"We wish you would use these grounds, as they were constructed for your benefit. Thanks for calling and come again."

A legible, not-too-detailed line diagram of the plant layout occupies the last page of the folder. Plant units are clearly marked with the number listed for each unit in the descriptive sections so that one can easily follow and understand the diagram.

The cost of printing such a pamphlet as Mr. Cameron has prepared is small and the good will to be gained by its distribution to visitors is well worth the effort required. We feel sure Mr. Cameron would be glad to send a copy of his descriptive plant folder to all interested sewage works personnel.

Too True—Sometimes!

At least two Member Associations have been enlightened and entertained, to express it mildly, by outstanding foreign sewage works experts. The New York association hasn't yet recovered from Dr. Aleksei Ivanov-Kamnev's learned discourse on "American Sewage Works Practice Reviewed by a Russian Expert."

At its May meeting, the Pennsylvania association highlighted the annual dinner by presenting Federigo Bracciano, pHD, Direttore di Recera, Sanitanio, Universita di Bologna, eminent sewerage historian, whose hilarious discussion of "Ancient and Modern Developments in Sanitation" had many of the Pennsylvanians literally rolling in the aisles.

It's no concidence that these unique foreign "experts" were one and the same—that master of wit and dialect, Allan Johnstone, of Wallace and Tiernan, Inc. Mr. Johnstone's talents, however, are not confined to humor alone. The deft barbs of truth hidden in many of his remarks make them stick. As an example, here is Mr. Johnstone's definition—as Dr. Federigo Bracciano—of a sewage treatment plant:

"Just a big hole in the ground—
Designed by an optimist,
Built by a materialist,
Equipped by a hypnotist,
Operated by a pessimist!"

Editorials

TIME TO MODERNIZE PUBLIC WORKS CONTRACTS

The following letter, received from an engineer representing a large company manufacturing equipment for sewage works, pertains to a situation that deserves immediate consideration and action:

"In the July issue of SEWAGE WORKS JOURNAL you have an editorial, 'Municipal Buying Practices Need Streamlining,' which I have read with much interest. The last paragraph is especially worthwhile.

"I most heartily agree with you on the need of streamlining purchasing methods to the end that cities will get better prices and deliveries.

"The need for changes is, however, not confined to ordinary buying procedures but is equally great in the field of municipal contracts.

"It seems as though most contract documents and forms were adopted by our various cities in the dim and distant past. Precedent, being what it is to the legal mind, apparently cannot be changed, and so our cities are still using the old time-honored phraseology.

"My company has hundreds of municipal contracts to examine each year and many of them come to my attention. In general, they are far from 'streamlined' in any sense of the word, and are obsolete in many respects as judged by present-day business methods.

"Many contracts contain unreasonable clauses which add to the business risks to be assumed. Additional risks may produce additional costs and, of course, result in higher prices.

"At the present time our national economy is very unstable and most manufacturers of capital goods find it necessary to protect themselves against inflation, an uncertain material market, and the vagaries of labor. This is particularly true whenever considerable time is required to manufacture the equipment. These people are now placing price protection or escalation clauses in their proposals. But municipal contracts seldom provide for such clauses and the manufacturer is compelled to bid with firm prices. The net result is that bids are usually submitted with the full escalation percentage already added in. This penalizes the cities in that they agree to pay more than they usually would had such clauses been in effect.

"There now are hundreds of patents on sewage and water treatment processes, and it is customary for cities to include process patent clauses in water and sewage works contracts. These clauses usually provide that the contractor shall save the city from the payment of damages should the city violate any patent connected with any treatment process. I can see no reason why a manufacturer of a standard piece of equipment, such as a motor or a pump, should be asked to protect the city against a suit for the city's alleged process patent violation when the motor or pump has no connection with the process. If it is to the city's advantage to use a patented process it should be willing to pay for that advantage. But why pass the buck to the machinery maker who knows nothing of the processes involved? If cities are going to continue to write process patent clauses in their contracts, they will have to pay premium prices for the equipment they buy.

"There is a loud cry heard from many sources that bids are too high and have to be thrown out because they exceed engineers' estimates. Cities are, in part at least, responsible for this situation by writing uncertainties, process patent clauses, 'as the engineer directs,' and similar phrases in their contracts. Elimination of such potential items of cost will lower bids and make for better relationships between the contracting parties."

This letter speaks for itself, frankly and succinctly. Consulting engineers, who usually prepare contract documents, are in the best position to bring about the modernization that is suggested. Patent holders can cooperate constructively. Municipal engineers and purchasing authorities should act aggressively to direct the attention of city councils and legal advisors to the shortcomings of contract forms in present usage.

There are signs that the huge log jam of sewage works construction is about to give way. Waste, confusion and unnecessary delay can be avoided if presently antiquated contractual provisions are replaced or brought up to date.

W. H. W.

APOLOGIES TO LOS ANGELES COUNTY

Mr. A. M. Rawn, Chief Engineer and General Manager of the County Sanitation Districts of Los Angeles County and Past President of the Federation, has called attention to an erroneous statement in the editorial "The Back Door to the River," contained in the September issue of THIS JOURNAL.

The statement at issue reads "The 'Portland Plan' is based on experience at the Los Angeles County Sanitation Districts plant, where digested sludge has been discharged to the Pacific Ocean." Mr. Rawn points out that the reference to the Los Angeles County plant is quite incorrect, and continues:

"We have never discharged any sludge of any character through our outfall to the Pacific Ocean. All of the sludge of our plant is retained at the plant, spread on drying beds and sold to a commercial fertilizer dealer. As an asset to the plant it has a current annual value of nearly $50,000."

Our sincere apologies go to Mr. Rawn and to the Los Angeles County Sanitation Districts for the erroneous assertion. It was reported on the basis of a verbal statement that was obviously misunderstood. The writer's failure to secure verification is inexcusable.

Commenting further on the original editorial, Mr. Rawn expressed the opinion that it is "too strong," and refers to present difficulties in the Southwest in procurement of equipment and materials for sludge processing disposal. It should be noted, however, that natural conditions in the Southwest—hot, dry climate; ample lagoon areas; loose, sandy soils; and the need for water conservation—generally preclude any serious sludge disposal "emergencies."

Mr. Rawn also introduces another argument in support of the original thesis—the fertilizer value of sludge when returned to the soil. Mention of this was purposely omitted in the editorial because it was felt that stream sanitation considerations alone should justify proper disposal of sewage sludge. Many conservationists feel that the loss of any sewage solids to streams represents a shameful waste of soil organics.

"The Back Door to the River" was intended as a check on the kind of thinking that leads to practices that are not in accord with the long range objectives of waste treatment and disposal. Readership response to the editorial has been gratifying.

W. H. W.

Proceedings of Member Associations

NEW YORK STATE SEWAGE WORKS ASSOCIATION

Spring Meeting

Niagara Falls, N. Y., June 4–5, 1948

The 1948 Spring Meeting of the New York State Sewage Works Association was held at Hotel Niagara, Niagara Falls, N. Y. on June 4–5, 1948. Registration included 146 members and guests.

The program was diversified, with subjects of interest which appealed to all attending. The June 4 program presented the following excellent papers and discussions:

"Operating Problems from Leather Wastes at Balston Spa." By William Porter, Supt. of Sewage Treatment, Balston Spa, N. Y. Discussion by W. R. Schreiner, Dist. Engineer, New York State Department of Health, Glenfalls, N. Y.

"Treatment of De-inking Waste—Pilot Plant Scale." By Philip F. Morgan, Chief Development Engineer, National Council for Stream Improvement, Kalamazoo, Michigan. This paper was illustrated by a color film.

"Results of Two-Year Study of Stream Pollution Control by the State Legislative Committee and Plans of the State Department of Health in Connection Therewith." By Earl Devendorf, Asst. Director, Bureau of Environmental Sanitation, New York State Department of Health, Albany, N. Y.

"Joint Action by Communities for Pollution Abatement." By Earl F. O'Brien, Holmes, O'Brien & Gere, Consulting Engineers, Syracuse, N. Y.

"The Formulation of Basic Policies to Control the Discharge of Industrial Wastes into Sanitary Sewers." By Thomas M. Riddick, Consulting Engineer, New York, N. Y.

"Trickling Filter Operation Problems." By George H. Bush, Supt., Brighton Sewer Commission, Brighton, N. Y.

The noon luncheon of the Association on June 4 featured the address of Mr. Devendorf listed above. Presentation of rating awards was accomplished by J. A. Salvato, chairman of the Rating Committee. Mr. L. A. Sammis was awarded a loving cup in recognition of the excellence of his report on operation of the Pilgrim State Hospital sewage treatment plant. Mr. Uhl T. Mann was awarded a previous winner's certificate in recognition of his report of the operation of the Ley Creek sewage treatment plant.

The Dinner-Dance, held the evening of June 4, featured special entertainment arrangements for the ladies and was greatly enjoyed by all.

The morning program of June 5 was devoted to a panel discussion by Dr. George E. Symons on "Sludge Digestion Tank Heating and Related Problems." Participating on the panel were Paul E. Bardet, Paul J. Cerny, A. J. Fisher, George F. Fynn, G. W. Moore, C. R. Velzy, and J. D. Walker. The spirited discussion and interchange of ideas made the morning session an outstanding success.

An inspection trip of the Niagara Falls sewage treatment works concluded the meeting.

A. F. DAPPERT,
Secretary

FLORIDA SEWAGE WORKS ASSOCIATION

Sixth Annual Meeting

Gainesville, Florida, June 6–12, 1948

The Sixth Annual Meeting of the Florida Sewage Works Association was held on the University of Florida campus at Gainesville on June 6–12, 1948. The meeting was held jointly with the Sixteenth Annual Florida Short Course on Water Supply and Sewage Treatment. Members attending the meeting numbered 33.

Assoc. Prof. John E. Kiker, Jr., conducted the Association members on a tour of the recently completed University of Florida sewage treatment works.

The first discussion period included the following presentations:

"Latest Viewpoints on the Chlorination of Sewage." By N. S. Chamberlin, sanitary chemist, Wallace & Tiernan Company, Inc.

"Vocabulary of Sewage Treatment." By John G. Patterson, Florida State Board of Health.

"Primary Sewage Treatment Processes." By Ralph L. Metcalf, Florida State Board of Health.

"Secondary Sewage Treatment Processes." By Wilson T. Calaway, University of Florida.

"Arithmetic of Sewage Treatment." By John E. Kiker, University of Florida.

A discussion of "Sewage Plant Maintenance and Safety Methods" was given by R. W. McDaniel, Superintendent of sewage treatment plants, Naval Air Station, Jacksonville. David B. Lee, director, Bureau of Sanitary Engineering, Florida State Board of Health, presented the state regulations concerning sewerage and sewage treatment. J. G. Patterson and J. W. Wakefield, Florida State Board of Health sanitary engineers, discussed "Status of Treatment in Florida," and "Principles of Stream Sanitation," respectively.

Discussions of the following topics were presented at other sessions of the Association:

"Sewerage Design, Construction, and Records." By B. F. Borden and W. J. Parks, of Reynolds, Smith, and Hills, consulting engineers.

"Citrus Waste Treatment." By R. R. McNary, Florida Citrus Commission; E. G. Wheelhouse, Yeomans Bros. Company; and Asst. Prof. George R. Grantham, University of Florida.

Professor Grantham also described "Metering Devices and Methods Used in Connection With Sewage," and R. M. Hoyt, Solvay Sales Corporation, spoke about "Safety Procedures in the Handling of Chlorine Cylinders."

The Federation was represented by its president, George S. Russell, who spoke at the opening of the short course on "What the Federation Means to the Florida Sewage Works Association."

The annual business meeting of the Association was held June 7. David B. Lee and President Russell discussed the conditions and actions that would precede the acceptance by the Federation of an invitation to hold the 1952 Convention in Florida. Joe Williamson, Jr., presented the report of the Research Committee. The Kenneth Allen Award Committee recommended that David B. Lee receive the award for outstanding services in the improvement of sewage treatment works practices in Florida. The following officers were elected for 1948–49:

President: J. Robert Hoy, Jacksonville
Vice President: S. Keith Keller, Clearwater
Secretary-Treasurer: Perry M. Teeple, Jacksonville

PERRY M. TEEPLE,
Secretary-Treasurer

OHIO SEWAGE AND INDUSTRIAL WASTES TREATMENT CONFERENCE

Twenty-Second Annual Meeting

Dayton, Ohio, June 23–25, 1948

The Twenty-Second Annual Meeting of the Ohio Conference on Sewage Treatment was held at the Dayton-Biltmore Hotel, Dayton, Ohio, June 23–25, 1948. Action was taken to change the name of the Conference from Ohio Conference on Sewage Treatment to Ohio Sewage and Industrial Wastes Treatment Conference. A total of 192 members and guests registered for the meeting. A large proportion of the new members registered were representatives of industry.

The first session was opened by Chairman L. B. Barnes on Wednesday afternoon. George S. Russell, President FSWA, greeted the group and discussed the status and activity of the Federation.

During the brief business session that followed, officers elected for 1948–49 were:

Chairman: E. F. Wittmer, Columbus
Vice Chairman: Robert Bowman, Findlay
Secretary-Treasurer: G. A. Hall, Columbus

The Conference adopted a resolution instructing the Secretary to write a letter to the Surgeon General, Washington, D. C., suggesting "that Mr. L. A. Danse, Supervisor, Materials and Process, Production Engineering Section, General Motors Corporation, be recommended as the industrial representative on the Water Pollution Control Advisory Board created by the Water Pollution Control Act of 1948 (80th Congress—S–418)."

Robert Howell, water and sewage plant foreman, Ravenna Arsenal, then presented a paper on "Preventative Maintenance at Sewage Treatment Plants," which was discussed by Lt. Col. Anthony Fleming, post engineer, Ravenna Arsenal. The remainder of the afternoon session was devoted to a manufacturers' forum during which the following subjects were presented and discussed:

"pH Control as Applied to Industrial Wastes." By W. N. Greer, Leeds and Northrop Company.

"Reduction of Cyanide Wastes." By H. B. Snyder, Jr., Wallace & Tiernan Company.

"Digester Heat Exchangers." By L. E. Langdon, Pacific Flush-Tank Company.

"Swing Diffusers for Aeration." By Miles Lamb, Chicago Pump Company.

"Impingement Aeration." By J. D. Walker, Walker Process Equipment Company.

The Thursday morning session opened with a breakfast and operators' forum which was lead by E. F. Wittmer. Following the forum, the Ohio River Valley Water Sanitation Compact was discussed by Hudson Biery, chairman of the commission. Mr. Biery also discussed the Federal Water Pollution Control Act, recently passed by the 80th Congress. H. W. Streeter, sanitary engineer (retired), USPHS, then presented a paper on "Stream Standards."

During the afternoon separate sessions dealing with sewage treatment and industrial waste treatment were held. In the session on sewage treatment, the following papers were presented:

"Elimination of Storm Water from the Wadsworth Sanitary Sewer System." By Frank Randall, city engineer, Wadsworth, Ohio. This paper was discussed by Homer Knox, sani-

tary engineer, Ohio Department of Health.

"Performance of Roughing Filters at Lancaster, Ohio." By E. Dwight Keller, asst. city engineer, Lancaster, Ohio.

"Performance of Conventional Trickling Filters as Influenced by Hourly Flow and Load Variations at Norwalk, Ohio." By C. P. Clark, chief sewage works operator, Norwalk, Ohio.

Operating experiences under the heading "Extra Dividends from Preaeration" were presented individually by the following operators: Carl Bauer, Salina; W. E. Conrad, Wooster; and Herbert Hansen, Revanna. Further discussions were provided by Floyd G. Browne and Paul A. Uhlmann, consulting engineers, Marion, Ohio.

In the industrial wastes treatment section, B. M. McDill, Ohio Department of Health, spoke on the subject "An Approach to Industrial Wastes Treatment Problems." L. A. Danse, of General Motors Corporation, Detroit, Michigan, followed with "Industry's Responsibility in Waste Treatment." Only two fields of industrial waste treatment were featured at this session, primarily because of their local importance. These were plating and paper wastes. Papers presented which discussed these particular areas of waste treatment were:

"Industrial Waste Treatment Plant, New Departure Division, G. M. C., at Sandusky, Ohio." By H. D. Unwin, Albert Kahn Associates, Detroit, Mich., described the design and treatment of facilities for wastes from the manufacture of ball bearings.

"Operating Results." By George McBride, Detroit, Michigan.

"Waste Treatment Practice for the Paper Industry." By Dr. Harry W. Gehm, New York City.

The final session of the Conference, held Friday morning, included the presentations "Should Prevailing Sewer Rental Rates be Adjusted?" by A. H. Niles, Toledo; "Current Features of Design," by C. S. Finkbeiner, Toledo; and "Design and Operation of Waste Treatment Facilities of Belle Center Creamery and Cheese Company," by Don Neil, Belle Center.

G. A. HALL,
Secretary-Treasurer

KENTUCKY–TENNESSEE INDUSTRIAL WASTES AND SEWAGE WORKS ASSOCIATION

Second Annual Meeting

Chattanooga, Tenn., August 23–25, 1948

The Second Annual Meeting of the Kentucky-Tennessee Industrial Wastes and Sewage Works Association, meeting jointly with the Kentucky-Tennessee Section of the AWWA, was held at the Patton Hotel, Chattanooga, Tenn., August 23–25, 1948. Members and guests registering totaled 253.

The program included 2½ days of technical sessions, concluded by an inspection trip to the Chattanooga City Water Company filter plant, following which a luncheon was enjoyed.

A joint session opened the program Monday morning, during which talks were given by V. M. Ehlers, vice president, FSWA, and A. P. Black, vice president, AWWA. Following the showing of the movie "Clean Waters," the annual business session was held.

The Monday afternoon program of the industrial wastes sewage works section included the following papers:

"Experiments on Anaerobic Digestion of Wool Scour Wastes." By M. T. Singleton, Wiedeman & Singleton, engineers, Atlanta, Ga.

"Research on Rapid Analytical Techniques in Water and Sewage Analysis." By George W. Reid, Georgia Institute of Technology, Atlanta, Ga.

"Sanitary Research at the University of Florida." By John E. Kiker, University of Florida, Gainesville, Fla.

The Tuesday morning joint session was presided over alternately by G. R. Kavanagh and Julian R. Fleming. The program included a discussion on "In-Plant Training," by W. A. Hardenbergh, editor, *Public Works Magazine,* New York City; and a joint paper by Abel Wolman, consultant, and Arthur Gorman, sanitary engineer, Atomic Energy Commission, Washington, D. C., on "Nuclear Fission Operations and the Sanitary Engineer."

The Tuesday afternoon session of the industrial wastes and sewage works section, with Chairman Fleming presiding, heard a paper by Fred D. Doutt, Champion Paper and Fiber Company, Canton, North Carolina, on "An Experience in River Improvement as Related to Changes in the Mill," and concluded with a paper and panel discussion led by Lloyd K. Clark, Association of American Railroads, Baltimore, Maryland, on "The Place of the Sanitary Engineer in Industry." Additional comments on this subject were made by James Ellis, of the Tennessee Eastman Corporation, Kingsport, Tennessee.

The final technical session on Wednesday morning included a panel discussion on water bills. A joint business session followed during which sewage works section officers elected for 1949 were:

Chairman: Grant S. Bell, Lexington, Ken.

Vice Chairman: S. Leary Jones, Nashville, Tenn.

Secretary-Treasurer: R. P. Farrell, Nashville, Tenn.

R. P. FARRELL,
Secretary-Treasurer

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
New York State Sewage Works Assn.	Hotel Pennsylvania, New York, N. Y.	Jan. 21–22, 1949
Montana Sewage Works Assn.	Johnson Hotel, Great Falls, Mont.	April 7, 1949
Institute of Sewage Purification (Summer Conference)	Herrogate, England	June 20–24, 1949
Pennsylvania Sewage and Industrial Wastes Assn.	Nittany Lion Inn, State College, Pa.	Aug. 24–26, 1949
Iowa Sewage Works Assn.	Hotel Kirkwood, Des Moines, Ia.	Sept. 20–22, 1949

Reviews and Abstracts*

The Periodicity of Dosing Percolating Filters. By C. Lumb and J. [illegible]arnes. *The Surveyor,* **107**, 387–391 (July 30, 1948).

Experimental studies of one year duration on two 6-in. diameter by 6-ft. deep filters, dosed with settled sewage at the rate of 65 gal. per cu. yd., were made using continuous and intermittent (10 min. intervals) application of the sewage. The results of oxygen absorbed, 5-day B.O.D., nitrite nitrogen, nitrate nitrogen, and suspended solids measurements showed that intermittent dosing yielded a better effluent. Also, the growth on the stone of the continuously dosed filter was much greater with "ponding" finally developing while the intermittently dosed filter remained relatively clean.

Experiments of one year duration with filters dosed continuously and intermittently at 5, 10, and 20-minute intervals with the same amount of sewage per cu. yd. per day showed that the intermittently dosed filters all yielded superior effluents to the continuously dosed filter and also remained in a more clean condition. The results of these experiments were checked by changing the continuously dosed filters to intermittent and the intermittently dosed to continuous and again the intermittent dosing provided a better effluent and a more clean filter.

Experiments were made on two 65-ft. diameter beds both receiving the same amount of sewage per day. The four-arm rotary distributor on one was rotated once in 44 seconds while the other was rotated once in 256 seconds, thereby providing almost continuous dosing for the former and intermittent for the latter. Results over a 12 month period showed that the intermittent dosing yielded a superior effluent and did not "pond" while the continuously dosed filter showed considerable "ponding." The authors conclude that filters operated with an appreciable time interval between doses function more efficiently and are better able to withstand heavier loading than beds fed at short intervals equivalent to continuous dosing.

From the results of small experimental filters and plant size filters the authors estimate the dosing interval giving most efficient oxygen absorption and 5-day B.O.D. removal to be from 4 to 9 minutes. The authors also report that from their practical experience over a period of years beds equipped with slowly revolving distributors exhibit less tendency to "pond" and require less forking-over than do beds equipped with rapidly rotating distributors.

Harold B. Gotaas

Sewage Purification Experiments—Sheffield Investigations (Discussions). *The Surveyor,* **107**, 235–237 (May 7, 1948).

It was observed that the authors in their investigations at Sheffield had set out to improve the bio-aeration paddle as an aerating device. The conclusion was reached that a triangular paddle with the length about three times the base, operated at twice normal speed, gave much greater efficiencies than did the original 10-in. by 7½-in. blades. The new paddle increased the efficiency of the plant at Chesterfield and one of the units at Sheffield 40 to 50 per cent. It was concluded that a blade 15½ in. by 5 in. wide at the base was best for a full-scale plant.

In replying to the discussions one of the authors said that doubling the number of paddles and operating at the original speed of 15 r.p.m. would not be as effective as the standard number of blades operated at twice the speed of rotation. Doubling

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* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage Works Assns., 325 Illinois Bldg., Champaign, Ill.

the number of paddle wheels would be more effective.

T. L. HERRICK

Secondary Mechanical Filtration of Sewage Effluent. By HAROLD WILSON. *The Surveyor,* **107**, 357–359 (July 9, 1948).

The fine humus or activated sludge floc remaining in the settled effluents of modern trickling filters and activated sludge plants is responsible for much of the remaining impurity in the effluent, and may be dangerous in some localities. In particular this may be so where the sewage contains large numbers of the eggs of intestinal parasitic worms or of amoebic cysts. Mechanical filtration or straining of such effluents is costly but may be found desirable where known dangers to health must be removed; such measures may be found necessary to bring the effluent within the local rivers board standards or to make the effluent safe for irrigating vegetable crops.

Probably the reason that filtration has not been widely adapted is the difficulty of cleaning such filters when the surface becomes clogged. The sealing film must be removed by backwashing or by allowing it to dry, after which it may be readily removed. In the early days of trickling filters a much finer grained medium was used than is in common use today. Furthermore, when working at low rates, around 50 gal. per cu. yd. per day, the humus was retained in the bed for long periods, even with fairly coarse grained filters. Such residual humus could be readily settled out. Present day high rate filters produce a gelatenous humus that is difficult to settle. Perhaps another reason such filters were not widely adapted was the desire to avoid large volumes of thin sludge resulting from backwashing.

Results are available at two cities in South Africa on the effect of filtering humus tank effluents. Results obtained by filtering the effluents through paper in the laboratory at the Pretoria sewage works are shown in the following tabulation. The figures are averages for the year 1947. The effluents were filtered through No. 12 Whatman filter paper.

Sample	5-day B.O.D. (p.p.m.)	Ammonia Nitrogen (p.p.m.)	Albuminoid Nitrogen (p.p.m.)	Suspended Solids (p.p.m.)
Singe Filter Bed:				
A	34.5	18.5	2.4	39.0
B	10.0	17.5	1.3	—
Primary Stage Filter Bed:				
A	41.5	29.0	2.9	47.0
B	14.5	27.5	1.6	—
Second-Stage Filter Bed:				
A	23.5	10.0	1.7	29.0
B	7.0	9.5	1.1	—

A—Humus tank effluent. B—Humus tank effluent filtered through paper.

Actual plant results are available from the records of the five Johannesburg sewage works. At the Klipspruit works the straining filters are cleaned by squeeges and only a minimum of backwash water is used. At the other four works the sand filters have 2 ft. of 1½-in. stone over the underdrain system, and overlaid by 6 to 9 in. of river sand. According to a paper presented in 1934 the filters are operated at a rate of 225 to 300 gal. (Imp.) per sq. yd. per day. The Klipspruit straining filters (Hamlin) are at present passing about 560 gal. per sq. yd. per day. A brief summary of results follow. The figures are averages of weekly samples for the year ending June 30, 1947.

In 1944 a special study was started at Johannesburg on the numbers and types of intestinal parasites in the sewage. "Of the 37 specimens 8 had been subjected to sand filtration and 2 had passed through land filtration. In these 10 specimens no ova or cysts were found. On the other hand, of the remaining 27 sample speci-

	Effluent Analyses			
	Nitrate Nitrogen (p.p.m.)	Ammonia Nitrogen (p.p.m.)	Albuminoid Nitrogen (p.p.m.)	5-day B.O.D. (p.p.m.)
Aetna Works:				
Primary filter—humus tank	8.0	30.7	4.1	—
Sand filter	13.0	22.5	2.2	19.3
Burma Works:				
Primary filter—humus tank	18.0	12.4	3.4	—
Sand filter	21.0	10.4	1.4	5.6
Cydna Works:				
Primary filter—humus tank	12.0	12.8	2.3	—
Sand filter	10.0	9.5	1.7	9.8
Delta Works:				
Activated sludge plant	13.0	22.0	7.4	—
Sand filter	20.0	16.8	2.6	18.7
Klipspruit Works:				
Humus tank	12.0	28.0	3.5	—
Final Hamlin filter	12.0	21.1	2.3	7.3

mens not subjected to sand or land filtration, 17 contained ova and in 10 cases cysts as well. It is thus clear that ova of parasitic worms and cysts are common in various forms of sewage effluent but that they are eliminated, at least to a very considerable extent, by sand or land filtration."

It appears that secondary straining filters are effective in improving the quality of effluents from biological processes of sewage treatment.

T. L. HERRICK

Control of Flies Breeding in Percolating Sewage Filters. *The Surveyor,* **107,** 314 (June 18, 1948).

A report has been made by two members of the Water Pollution Research Board which describes tests on the application of DDT and Gammexane to trickling filters for the control of *Psychoda.* At four plants where the media had a light coating of biological film all treatments were successful. At two plants where the filters were heavily loaded and carried a heavy coating of film the applications had a negligible effect; better results were obtained in a later application when the filters were in a cleaner condition.

At one plant tests indicated reductions of 70 to 75 per cent in the numbers of *Psychoda* trapped with applications of 2 lb. of Gammexane or 10 lb. of DDT per acre every 4 weeks. Applications of half these amounts every 2 weeks showed similar results. Preliminary tests indicated that samples of effluent from certain filters treated with 10 lb. of DDT or 1 lb. of Gammexane per acre contained concentrations of insecticide toxic to trout.

T. L. HERRICK

Clogged Sewage Filters. *The Surveyor,* **107,** 305 (June 18, 1948).

It may be said that most cases of severe ponding of trickling filters is due to overloading. Overloading may be due to design errors; perhaps the strength and peculiarities of the sewage were not given due consideration, or adequate sludge disposal facilities were not provided, thus adversely affecting sedimentation in the primary tanks. Again, it may be due to inadequate capacity for the volume of flow to be treated. "Inadequate arrangements for the disposal of sludge have probably caused more trouble and inefficiency on sewage works than any other single factor."

Among the more common remedies are forking, chlorination, and resting of the beds. Chlorination has not been used much in England. In recent times more scientific methods for preventing clogging have been developed, particularly recirculation and alternating double filtration. Investigations at Sheffield have shown that recirculation of well nitrified effluent is particularly effective in curing ponding. These methods necessitate certain alterations, but once they are made ponding can be cured without upsetting the treatment process.

T. L. HERRICK

The Future Sewage Disposal Works of the Birmingham Tame and Rae District Drainage Board. BY F. C. VOKES. *The Surveyor,* **107,** 137 (March 12, 1948).

The Birmingham Tame and Rea District Drainage Board serves an area of 163 sq. miles and a population of about 1,250,000.

The Saltley works will be inadequate in the near future. At present the sewage and storm water from a population of about 900,000 is settled in manually cleaned tanks. Two smaller works, at Ashold and at Tyburn, will likewise soon be inadequate. Settled sewage from all three works is conveyed to Minworth, about five miles from the Saltley works. The existing bio-aeration plant and percolating filters at Minworth are inadequate to treat the expected future flow, but the adoption of alternating double filtration will enable the filters to carry the load.

It is contemplated that a new sewer will be constructed paralleling the present conduit between Saltley and Minworth. The two conduits will handle the ultimate maximum flow of 432 m.g.d., 360 gal. per person from a population of 1,200,000. The new works will be designed to provide complete treatment for a maximum flow of 180 m.g.d., and the storm water tanks will give nearly 1½ hours settling for a maximum additional storm flow of 252 m.g.d.

New construction at the treatment works will include bar racks, screens, macerators, grit channels and grit washing equipment, storm water tanks, sedimentation tanks, travelling distributors for the trickling filters, additional humus tanks, and primary sludge digestion tanks. The sedimentation tanks will provide 2 hours settling for the maximum flow. They will be rectangular and 230 ft. long. A travelling scraper, electrically driven, will be used to move settled solids to the hoppers at the inlet end of the tanks.

The existing filters cover 42 acres and have an average depth of 6 feet. The medium is approximately 1½ in. in size and is for the most part slag, quartzite, and granite. Fixed spray jets are provided on two-thirds of the area and the remainder is equipped with travelling distributors. A little more than one-third of the dry weather flow is given 1 hour treatment in the bio-aeration plant before passing to the filters.

The new construction will provide travelling distributors for the entire filter area. The adaption of alternating double filtration will enable the present filters to handle the load and allow eventual abandonment of the bio-aeration plants. When the flow reaches one-half the maximum, alternating filtration will cease and the entire area will be used for single filtration.

Primary digestion tanks only will be required as adequate provision is at hand for secondary digestion at the sludge treatment works a mile away. A capacity of 2 cu. ft. per capita will be provided in the primary digestion tanks. This will mean about 30 days retention in the primary tanks. The tanks will be 80 ft. diameter with floating covers.

At the Yardley works it is contemplated making such extensions as are needed to provide capacity until such time, in the future, that the sewage from this area can be taken to Minworth for treatment. Plant extensions will include additions to the bio-aeration plant, additional humus tanks, and additional primary sludge digestion tanks.

The Coleshill works was planned in five units, two of which have been completed and placed in operation. The capacity at present is 6 m.g.d. (Imp.). The activated sludge process with diffused air is employed. It is thought that power plant extensions and additional blower capacity will add materially to the capacity of the plant.

T. L. HERRICK

The Inspection and Control of Trade Waste Effluent Discharges. By M. A. Kershaw, Jr. *Journal of the Institution of Sanitary Engineers,* Vol. XLVII, Part 1, p. 23 (Jan.-April, 1948). *The Surveyor,* **107,** 130 (Mar. 5, 1948).

The development of governmental control of industrial wastes in Britain is briefly outlined. A number of Acts of Parliament and reports of Commissions resulted in the adoption of the Public Health (Drainage of Trade Premises) Act in 1937. No information of the Act is given other than that it gives industries the right to discharge their trade wastes to the sanitary sewers, authorizes local authorities to make bylaws governing control of those wastes, and sets up general conditions which can be used as a guide in setting up standards.

The author's Local Authority has used the Act as a guide and means of persuasion and has developed a system of cooperation and inspection which is successful. The Authority contains such a diversity of industries that it was considered unwise to attempt to make bylaws to control all types of wastes. While the need for control was recognized, the local Council had previously adopted a policy designed to encourage industry to move into the area and, hence, ruled out assessments against industries for receiving, pretreating, or treating their wastes. Consequently, all recommendations for control of trade waste effluent are adopted by individual agreement between each industry and the Authority.

Pretreatment is desirable in order to: (1) protect sewer fabric; (2) reduce to minimum sewer blockages; (3) obviate, as far as possible, damaging reaction due to discharge of different wastes to the same line; and (4) prevent, as far as possible, interference with treatment processes. Pretreatment is recommended when wastes are constituted on any of the following broad lines: (1) excessively high temperature; (2) large quantities of, or extremely heavy, suspended solids; (3) certain materials in solution; and (4) high acidity. Balancing (equalizing) tanks are also desirable to prevent "rush" or "bulk" discharges.

To show that the Local Authority is not dealing with the problem as a side line, a trained chemist was appointed on the staff of the sewage purification department as assistant trade waste effluent inspector. In 5 years genuine good will has been established between the Council and factory executives, and a workable system of control has been evolved. The system is set up in four phases:

1. Plans for New Factories: In cooperation with the building inspector all new factories are studied on the basis of size, products, and type and volume of wastes. Discussions are held with the factory representatives and recommendations are made relative to the discharge of wastes or to pretreatment.

2. General Survey: This is made in new factories when they are operating or in old plants. The officials are interviewed, the drainage system is investigated, diagrams are made, and data are obtained on the wastes. If sampling is needed the points are selected, and, where there is pretreatment, operating procedure is discussed. A record file is made for each industry and all data, diagrams, etc., are kept in it.

3. Routine Inspection: Subsequent inspections are made for obtaining samples and checking general maintenance and operation. Every inspection is recorded.

4. Special Inspections: These are made to investigate unusual discharges, sewer blockages, upsets to the treatment process, and complaints. Through the cooperation obtained as a result of frequent visits and the ready information obtained in the record file, special investigations have been made much easier.

The author has emphasized the value of keeping a complete index and making routine visits to each factory.

W. A. Hasfurther

Discharge of Waste Liquors into Public Sewers. *The Surveyor,* **107,** 172 (April 2, 1948).

In March, 1948, a case of considerable interest was heard at Solihull, Warwickshire, which involved the discharge of trade waste liquors into public sewers. The Public Health Act of 1936 and the Public Health (Drainage of Trade Premises) Act (1937), were invoked. The Solihull Urban District Council charged that the company had: "(1) On October 4, 1947, unlawfully discharged into a public sewer a trade effluent containing chromate without hav-

ing obtained the consent of the local authority, contrary to the provisions of the Public Health (Drainage of Trade Premises) Act, 1937; (2) on the same date relating to the same discharge, permitted to enter a public sewer matter likely to affect prejudicially the treatment and disposal of the contents of the sewer, contrary to Section 27 of the Public Health Act, 1936." Charges (3) and (4) were similar, relating to the discharge of chromate wastes on a later date. The company pleaded guilty to charges (2) and (4), and not guilty to the other two.

Testimony brought out the fact that in April, 1946, a discharge of trade wastes, believed to contain cyanide, upset the treatment process at the works and killed fish in the River Blythe. The Council at once sent written notices to all factories in the district calling attention to the requirements of the Drainage of Trade Premises Act. On Oct. 2, 1947, a sustained discharge of cyanide wastes was again noted, and while tracing this discharge, the chromate wastes were observed draining from the factory of the defendant company. The liquor contained 700 p.p.m. of chromate and 343 p.p.m. of acid. No application for consent to discharge such wastes was received.

Witnesses stated that the discharge of the wastes had caused much concern, as the source of the wastes was then unknown. It was contended that 1 p.p.m. of chromium would interfere with treatment and that 10 p.p.m. would cause production of a poor effluent.

It appears that at the time of the alleged discharges the company was dismantling the plant, preparing to vacate the premises. The defense was that, as the defendants were not in production, the discharges, though admitted, were accidental. As the factory was not in production the wastes were not part of a manufacturing process.

All charges were found proven. Fines totaling approximately $200 were assessed.

T. L. HERRICK

Small Scale Sewage Disposal. BY DONALD EASDALE. *The Surveyor,* 107, 165–166 (March 26, 1948).

Since the passage of the Rural Water Supplies and Sewerage Act, 1944, most rural authorities are obtaining advice on the sewerage problem of their districts and many schemes are being prepared. Comprehensive schemes for sewage works in rural areas are very apt to be expensive. Such schemes must be designed in small units, for single villages or small groups of villages.

Since the purpose of sewage treatment is to avoid or minimize pollution the design of the plant depends on effluent disposal possibilities. The nature of the soil and subsoil must be known if land disposal is to be considered. The seasonal variation in the quantity and quality of diluting water must be known if a stream is at hand. Local regulations must be considered.

Surface irrigation provides a simple method of disposal if a suitably isolated site is available. Surface irrigation of a tank effluent, which in most cases will be septic, should be done at a distance of at least 400 yards from any houses. In heavy soils a good method is the provision of a series of troughs ploughed on the contours, so that one trough fills before overflowing to the next.

If an underground soakaway is to be used a shallow soakaway drain in grassland should be selected. The trench should be 18 in. wide and 18 in. deep, with clay drain tile laid on the bottom with 1 in. between joints. Stone, 2 in. and over, is placed to a depth of 4 in. over the tile, followed by a layer of fine stone and finally top soil and turf.

In case trickling filters are required, a few points should be noted. Media for small filters should include nothing under 1½ in. in size. For loads up to 100 persons, rectangular filters with tipper and trough distributors should be provided. Larger units should be equipped with rotary distributors having few large jets which will not readily choke. If septic tank effluent is to be filtered, the filter volume should be 50 per cent greater than that for a nonseptic tank effluent. Filters for septic tank effluents should be enclosed to avoid odor nuisance. Enclosure of filters adds to the cost and may lead to neglect. The enclosed filter with forced down draft ventilation is outside the scale of plants under consideration. Humus tanks are a source of trouble around a small works. Discharge on land to soak or overflow to a stream is much more desirable.

Every effort should be made to hold to a minimum the operation attention required. For this reason septic tanks are preferred in most cases to other types of settling tanks. The capacity of septic tanks should be about 7 cu. ft. per person for the smallest sizes, ranging down to 5 cu. ft. per person for tanks to serve 500 people.

T. L. HERRICK

Occurrence of Tubercle Bacilli in Sewage and Experiments on Sterilization of Tubercle Bacilli Containing Sewage with Chlorine. BY K. A. JENSEN AND K. ERIK JENSEN. *Acta Tuberculosea Scandinavia,* **16–17,** 217–248 (1942–1943).

A review of the earlier work pertaining to the occurrence of tubercle bacilli in sewage is given. The work done by Musehold in 1900 on the viability of the organism in sewage and river water and sewage sludge indicated that virulence for guinea pigs was retained after storage of these various materials under different environmental conditions for 5 to 6 months. The same author was also able to demonstrate the presence of tubercle bacilli, by guinea pig inoculation, in sewage obtained from sanitoria where the sputum was not disinfected. Virulent tubercle bacilli were also present in biologically purified sewage.

It was later demonstrated that even after effective disinfection of sputum, sewage from sanitoria contained tubercle bacilli. The presence of tubercle bacilli in slaughter house and dairy wastes was also demonstrated by other investigators. These organisms belonged to bovine, avian, or human types.

The present authors made a comprehensive examination of sewage from various tuberculosis sanatoria. The presence of living, virulent tubercle bacilli in not inconsiderable numbers was a constant finding in purified sewage from tuberculosis hospitals and sanitoria. Their presence was also demonstrated even 100 meters from the outlet of the sewer discharging into a large body of water.

The authors state that although sterilization of sputum does a great deal of good, it is not sufficient. Examination of streams in districts with a high incidence of tuberculosis among cattle revealed that only in one instance could the presence of tubercle organisms be demonstrated. This was a specimen of water taken a short distance from the outlet of a sewer from a slaughter house, but since the isolated strain was of human type it probably came from the municipal sewer.

Bathing in the vicinity of sewage outlets may imply a certain danger of infection through aspiration of infected water or by way of mucous membranes of the eye and ear. It is positively objectionable to irrigate fields with sewage from sanitoria or use the sludge from sewage purification plant as fertilizer. Sludge from a sanitorium in a digestion tank where it had been stored for a year contained a rather large number of tubercle bacilli. The authors suggest that such sludge should be disposed of in hollows to remain for years and finally be covered with earth. The crust formed on top of the sludge should prevent it from being blown by the wind but the hazard of flies and other insects carrying the infected material still remains.

Previous work with the destruction of tubercle bacilli in sewage by chemicals is reviewed. Musehold found that in chemically treated sewage tubercle bacilli were not killed in 2 hours by the addition of 50 p.p.m. of chlorinated lime equal to 17 p.p.m. of chlorine. When twenty times this amount of chlorinated lime was added, the organism was rendered harmless. In another experiment tubercle bacilli were rendered harmless in 2 hours by the addition of chlorinated lime containing 33 p.p.m. of chlorine.

Sollazzo treated a tuberculosis hospital septic tank effluent, containing tubercle bacilli, with gaseous chlorine. With a chlorine residual of 20 p.p.m. immediately after the addition, tubercle bacilli were killed after 2 hours of contact. In plant experiments chlorine was added to septic tank effluent entering a 2-hour chlorine contact tank. Tubercle bacilli were found to be killed at an average chlorine concentration of 13 p.p.m., whereas 8.4 p.p.m. proved insufficient.

In similar experiments Barons treated Imhoff tank effluent going into a chlorine contact tank with a detention time of 2 hours. With 18 p.p.m. of chlorine added

and a residual of 0.5 p.p.m. at the end of the contact tank, no tubercle bacilli was found on repeated examination over a period of years.

Jusatz chlorinated the effluent after primary sedimentation and biological filtration and concluded that in order to kill the tubercle bacilli the addition of chlorine has to be at least sufficient to kill the colon bacilli and to reduce the total bacterial content by 99 per cent. The variations obtained by different investigators as to the amount of chlorine required to kill the tubercle bacilli can be ascribed to the differences in the character and strength of sewages treated.

In the disinfection experiments carried out by the authors, the B.O.D. of the sewage used was equal to that of a biological filter. The work was done with autoclaved sewage to which suitable amounts of tubercle bacilli were added. The sewage used was settled, filtered through paper and diluted with tap water. Chlorine was added in the form of calcium hypochlorite solution. The pH was kept at the neutral point. Ten thousand tubercle bacilli were added per ml. of the sewage. The addition of 20 p.p.m. of chlorine killed all the bacteria in 40 minutes in a sewage with a B.O.D. of 58 p.p.m. To another sewage with a B.O.D. of 43 p.p.m. and 100,000 tubercle bacilli added per ml., 20 p.p.m. of Cl added was able to sterilize the sewage after ½ hour. With 9 p.p.m. only a few remained alive after 30 minutes. A 3 p.p.m. dose had no sterilizing effect even after 4 hours. These results were obtained by culture method using Lowenstein's medium. A check of these results with guinea pig inoculations showed that the cultural method was reliable and agreed well with the guinea pig tests.

The above experiments were conducted with tubercle bacilli obtained from cultures. Tubercle bacilli in sputum, however, are more resistant than the cultivated organisms. Chlorination of sewage effluents, therefore, was undertaken to which sputum taken from tuberculous patients was added. The sputum was homogenized and added to sewage prepared as above. The sputum was homogenized with 4 per cent NaOH treatment for 30 minutes in order to eliminate the contaminating bacteria before addition to diluted sewage. The results showed that 9 p.p.m. of Cl was able to sterilize sewage containing 4,000 tubercle bacilli per ml. in 1 hour. Three p.p.m. of Cl in 4 hours had no effect. It appears that expectorated bacilli after preliminary treatment with alkali were not more resistant to chlorine than cultivated bacilli.

It is possible, however, that preliminary treatment with alkali may have dissolved the coating of sputum which might have protective action. The above experiment was repeated without preliminary treatment of sputum with alkali. The results were the same as in the previous experiment and it was therefore concluded that the preliminary alkali treatment had no effect on the resistance of the tubercle organisms to chlorine and that the resistance of cultivated and sputum tubercle bacilli to the action of chlorine was the same.

Chlorine added in the form of gas sterilized the cultivated bacilli added to sterile diluted sewage at the same concentration as calcium hypochlorite solution.

Plant-scale experiments were run on the disinfection of effluent from a tuberculosis sanatorium. In this sanatorium, spectum is collected and sterilized separately. The treatment plant consists of grit chambers, Imhoff tank, activated sludge (roofed in order to prevent droplets from escaping into the atmosphere) followed by chlorination and contact tank (average contact time 7 hours; minimum 3 hours). Chlorine is added automatically according to flow. Samples of raw sewage, activated sludge effluent, and chlorinated effluent were tested for the presence of tubercle bacilli by inoculation into guinea pigs and by cultivation on Lowenstein medium after homogenization with 4 per cent NaOH for 1 hour. It was found that sewage from this sanitorium constantly contained numerous virulent tubercle bacilli. It was further shown that an activated sludge plant does not reduce the numbers of tubercle bacilli appreciably. Sterilization of these organisms is only accomplished by the addition of 10 p.p.m. of chlorine.

H. HEUKELEKIAN

Drainage in Rural Areas. By J. C. WYLIE. *The Surveyor,* **107,** 257–258 (May 21, 1948).

Drainage schemes for 22 villages in Dumfriesshire have been completed during the

past 2 years. Work contemplated will bring the total number of systems to 80 in the county. For purposes of maintenance and administration, they will be considered by the local authority as a unified county service.

The treatment provided in any particular project will be governed by the recommendations on dilution in the Report of the Royal Commission on Sewage Disposal. Trickling filters will be provided in addition to settling where the available dilution makes it necessary. The dilution ratios vary from less than 70 to ratios greater than 300. The paddle type of rotary distributor is used where frequent attention is not required. The pressure jet type of distributor is utilized at locations where frequent attention is required because of pumping equipment, etc.

Sludge from septic tanks will be hauled to a central disposal point in a 500-gal. capacity tank on a 3-ton truck chassis. The plants are laid out with this method of handling sludge in view. At the disposal center, lagoons for receiving sludge will be formed by household refuse, the sludge deposited being ultimately covered over with additional refuse.

T. L. HERRICK

Differential Effect of 2, 4-D on Aerobic, Anaerobic, and Facultative Anaerobic Microorganisms. BY WINFIELD A. WORTH, JR., AND ANNE M. MCCABE. *Science,* **108**, 2702, 16–18 (1948).

Dichlorophenoxyacetic acid (2, 4-D) over a range of concentrations from 2 to .0002 per cent inhibited the growth of aerobic organisms tested. No inhibitory effects were observed with the facultative anaerobic organisms such as *Esch. coli, Staph. albus,* etc.

The lower concentrations of 2, 4-D increased the amount of growth over the controls of the anaerobes. *Cl. tetani* resembled in response to the facultative anaerobes but *Cl. welchii* and *Cl. botchulinum* varied in their response to 2, 4-D.

It was concluded that those organisms which require free oxygen for respiration are smothered by 2, 4-D. Those organisms capable of anaerobic respiration are not affected to any significant degree by 2, 4-D.

H. HEUKELEKIAN

Auckland Drainage Past, Present, and Future. BY D. M. ROBINSON. Report of Auckland (New Zealand) and Suburban Drainage League, July 8, 1948. 65 pages.

In this report the opposition to the Drainage Board's official Brown's Island scheme is voiced and an alternative scheme called the utilization scheme sponsored by Auckland and Suburban Drainage League is propounded.

The Drainage Board's official scheme consists of conducting the sewage from Auckland and the suburban area in a main intercepting sewer to Brown's Island in the harbor. The sewage is to be treated by coarse screens and detritus removal chambers, and discharged into the harbor channel at ebb tide from multiple outlets. The sludge will be digested and dried on sludge drying beds with the ultimate provisions of shipping wet sludge to sea.

This scheme is designed for a population of 550,000 in 1970. The capacity of the outfall provides for a maximum of 90 m.g.d., but only 60 m.g.d. will be treated in the proposed treatment plant. Chlorination will be practiced during extended periods of dry weather.

The Board estimated that a dilution ratio of at least 1 to 700 will be obtained in the dispersion area near the outfall. The zone of recovery in this area is estimated to be 3,000 acres and is claimed to provide complete recovery of the diluting water within a period of 4 hours after the discharge of clarified effluent.

The Auckland and Suburban Drainage League criticizes and opposes this scheme for the following reasons:

(1) Primary treatment will not prevent pollution of the harbor water. There is no provision for secondary treatment.

(2) Bacterial contamination of the bathing beaches will continue. Chlorination of the effluent to render it completely innocuous is not contemplated in the scheme. The complete chlorination of the effluent would entail the expenditure of $109,500 per year.

(3) Dumping of the sludge into sea instead of utilizing it for fertilizer.

(4) During wet weather up to 30 m.g.d. will be discharged without treatment other than screening.

(5) Dilution ratio of 700 to 1 is an overestimate. The estimate of the League is 136 to 1.

The Drainage League's alternative scheme is as follows:

The sewage would be treated by (a) grit and screen removal, (b) sedimentation or activated sludge process, (c) trickling filters, (d) humus tanks, (e) step aeration, and (f) effluent lagoons.

[Abstracter's note: It is not clear what will determine the selection of plain sedimentation vs. activated sludge or trickling filter beds. The scheme in this respect is hazy. By step aeration is meant the flow of the effluent over a series of steps for reaeration.]

The effluent lagoon is designed for final purification recovery of salts, and the destruction of the remaining bacteria. The growth of water weeds such as water hyacinth will be undertaken in order to transfer the elements in the effluent, such as nitrogen, phosphorus and potassium, to the weeds for harvesting and fertilizing value. It is estimated that the salts recovered in the water weeds would represent a value of $341,000.

Composting is an integral part of the scheme. All organic residues produced by the community are to be included in the compost. The organic residues to be composted consist of garbage, roadside cuttings, weeds, trade wastes, fish and vegetable market wastes, gorse, sawdust, shavings, etc. Sewage sludge and the water weeds will also be added. These residues will be shredded and spread out in covered composting bays. After each foot depth of organic residues, sludge will be sprayed and the layer will be limed. Compost bed depths will be 5 to 6 feet. It is expected that composting will not produce objectionable odor and pathogenic organisms will be destroyed by the heat generated in the compost.

The composting will be completed in about 2 weeks after which it will be removed to the maturing ground. At the end of 3 months the compost will have matured and will be ready for pulverization and bagging for sale as fertilizer. It will have about 40 to 50 per cent moisture at this stage.

For shipping and storage the material will have to be dried further to a moisture content of 25 per cent. A total of 160,000 tons of composted material with 25 per cent moisture is expected. After deducting the cost of production an annual profit of $283,000 is expected.

H. HEUKELEKIAN

The Mechanism of Methane Fermentation. By A. M. BUSWELL AND F. W. SALLO, JR. *Journal American Chemical Society*, **70**, 5, 1778–1780 (1948).

Three possible mechanisms of fermentation of acetic acid have been advanced by previous investigation: (1) Decomposition of acetic acid to H and CO_2 with subsequent reduction of CO_2 to CH_4 by the hydrogen; (2) Barker's theory of direct reduction of CO_2 to CH_4; (3) Buswell and Neave's idea of simple decarboxylation.

Against the first theory the authors say that H is found only in low concentrations in CH_4 fermentation of acetic acid. When Symons and Buswell passed H and CO_2 through a culture, only 3.5 liters of CH_4 was obtained in 100 days while in the same time such a culture fermenting acetic acid could produce 75 liters of CH_4.

The authors argue that the last mechanism, e.g., decarboxylation, is simpler and more direct than Barker's mechanism. This is not a necessarily valid argument. Internal oxidation-reduction could be brought about by the transfer of H from carboxyl to methyl group. The authors admit that the decarboxylation mechanism applies as a special case only to acetic acid and not to higher fatty acids, since the decarboxylation of propionic and butyric acids should yield ethane and propane which are not found in the gas.

Barker, Ruben, and Kamen (*Proc. Natl. Acad.*, **26**, 426 (1940)), found evidence for the reduction of CO_2 in the fermentation of acetic acid through the use of $C_{14}O_2$ by pure culture of *Methanisarcina methanica*.

By the use of isotopic $C_{14}O_2$, if the CH_4 is derived from CO_2 reduction, the CH_4 produced should be similarly marked. If the reaction was a simple decarboxylation CH_4 should not be so marked.

The authors fed acetic acid to a culture which had been previously fermenting acetic acid. To this radio-active sodium carbonate was added. The CO_2 in the gas was absorbed and the remaining CH_4 was

oxidized with a catalyst at 550° C. to CO_2, and the radio-activity was determined. The results showed that the activity of CH_4 is only a few hundredths of that of the CO_2. It was concluded that CH_4 is derived from the acetic acid itself and by some mechanism other than the reduction of CO_2. Simple decarboxylation is indicated but not definitely established.

H. HEUKELEKIAN

Sewage Treatment Plant of Tirlemont. BY M. N. DE BAENST. *La Technique de L'Eau,* 2, 4, 5–8 (April, 1948).

The Tirlemont activated sludge plant was designed for 30,000 and receives the sewage of 23,000. The plant consists of coarse screens, mechanical grit remover, primary settling tank with 40-min. detention, two aeration tanks with an average of 7-hr. detention, final settling tank, provision for reaeration, and heated digestion tank with gas collection. The average results obtained in p.p.m. were:

Sample	Susp. Solids	B.O.D.
Raw	284	192
Settled	62	110
Final	28	17

Gas production amounts to 15,750 cu. ft. per day, 52 per cent of which is used for heating the digester. Gas composition averages 33 per cent CO_2, and 55 per cent methane. Air dried digested sludge, containing 55 per cent moisture, 34 per cent volatile matter, 2 per cent N, 0.41 per cent P_2O_5, and 0.21 per cent K_2O, is sold to farmers and fruit growers.

WILLEM RUDOLFS

Treatment of Wastes from Natural Gums in Chewing Gum Manufacture. BY ROBERT P. LOGAN AND WILLEM RUDOLFS. *Industrial and Engineering Chemistry,* 39, 1673–1675 (December, 1947).

The waste resulting from the purification of natural gums prior to chewing gum manufacture contains sand, dirt, bark and dissolved substances. The latter have a high B.O.D. and are highly alkaline due to the detergent used in cleaning the gums. The waste also is red in color and is discharged at a temperature of around 140° F. A typical analysis of this waste is shown in the following table:

	Typical Anal.	Variations
5-Day B.O.D. at 20° C. (p.p.m.)	3,800	2,500–4,800
Total Solids (p.p.m.)	13,760	8,000–15,000
Ash, %	33.9	—
Suspended Solids (p.p.m.)	970	250–1,000
Ash, %	32.0	—
Total Alkalinity (p.p.m.)	1,800	—
Total Nitrogen (p.p.m.)	220	—
pH	10.5	

Suspended matter settles easily in ½ to 1 hour. In the manufacturing process the gum is washed successively, and it was found that about 50 per cent of the B.O.D. and volatile matter were contained in the first wash. However, the entire amount of waste was small (25,000 gal. per day) so that separate treatment of the various washes was not deemed advisable.

Chemical treatment, chlorination, aerobic treatment, anaerobic digestion, and sand filtration were all tried for treatment of these wastes.

Mesophilic digestion proved to be the most satisfactory, with sand filtration for the digester effluents, and final chlorination for color removal. Digestion reduced the B.O.D. to between 250 to 500 p.p.m. and filters could be operated at loadings in excess of 40,000 g.p.a.d. to reduce the B.O.D. to 60 p.p.m. The addition of final chlorination reduced this B.O.D. to 35 p.p.m.

H. GLADYS SWOPE

Report on an Investigation into the Use of Railway Passenger Car Toilets and the Nature and Quantity of the Toilet Wastes. Technical Reports No. 3 and No. 4 of the Association of American Railroads. Sanitation Research Project Joint Committee on Railway Sanitation of the Association of American Railroads (March, 1947, and December, 1947).

The investigations reported were undertaken to obtain basic data regarding human waste disposal on trains, and are to

serve as a basis for development of a satisfactory disposal method or treatment device for train sewage. The investigations are believed to be the first in this special problem of waste disposal.

The Joint Committee on Railway Sanitation, which directed the investigation, is composed of engineering and medical representatives of the Association of American Railroads (A.A.R.), and also engineers of the United States Public Health Service and the Canadian Department of National Health and Welfare. Abel Wolman was engaged as consultant director.

Technical Report No. 3 covers investigations of relatively short daylight or overnight runs while Technical Report No. 4 records investigations conducted on coaches and sleeping cars on transcontinental schedules. Report No. 4 also includes a series of charts showing graphic comparisons of the findings of both reports.

Significant results included in a summary of the data were:

1. Flushing water used in toilet rooms of coaches on daylight or overnight runs averaged 3.75 gal. per 100 passenger hours. This figure was higher on transcontinental runs.

2. Strength of wastes collected on daylight and overnight runs was about ten times that of ordinary domestic sewage.

3. Dry weight of sewage solids deposited on the road bed each hour during daylight or overnight runs was 0.121 pound. This was equivalent to 0.00235 lb. of sewage solids per mile of track.

RAY GOLLY

Acid Mine Water in the Anthracite Region of Pennsylvania. BY E. W. FELEGY, L. H. JOHNSON, AND J. WESTFIELD. U. S. Bureau of Mines Technical Paper 710, 49 pages (1948).

The objectives of this extensive investigation were: (1) to determine the present effects of acid drainage from mining operations in the anthracite region of Pennsylvania on the receiving streams in relation to the problems in stream sanitation now confronting the communities in this and adjacent regions; and (2) to indicate the effect on the streams of any program for mine-flood prevention or control which may be undertaken in the future.

Descriptions of equipment used, methods of collecting samples, preparation of reagents, and analytical procedures applied, are given. Several modifications of procedures outlined in "Standard Methods" were applied.

A glass electrode pH tester was used in this investigation. The mathematical development of a method for determination of average pH, and a graphical method are given. Two rather complete analyses of mine waters are included.

The costs for neutralization of acid mine drainage are discussed. Calculations of the cost of complete neutralization of the acid mine drainage at four widely separated points, selected at random, in the anthracite region are presented. Total costs are broken down into: cost for hydrated lime, labor, power, chemical, supervision, and interest and depreciation on plant and equipment.

Conclusions drawn from the results of the investigations of surface waters are:

(1) The pH of samples of river water collected at the same point generally are comparable.

(2) When volumes of flow at a given sampling point are approximately the same at different sampling times, the pH of the river water at those times compares closely.

(3) Free and total acidity or free and total alkalinity of the river water, as determined by chemical analyses in 1941 and 1946, is nearly the same for comparable volumes of flow.

(4) Changes in the acidity or alkalinity of the river water, as indicated by its pH or the usual analytical determinations, cannot be predicted by changes in volume of flow; in some instances decreased volumes of flow accompanied: (a) decreased alkalinity or increased acidity; (b) in others, increased alkalinity or decreased acidity.

(5) The changes in free and total acidity or free and total alkalinity (in p.p.m.) are much less marked than the corresponding changes in volume of flow, i.e., when the volume of flow changed in the ratio of 6:1 or more the acidity or alkalinity changed only in a ratio of 2:1 or less.

(6) The greatest acidity or alkalinity of the surface waters in many instances was less than 50 p.p.m. and in almost all instances less than 100 p.p.m.

(7) Apparently the relative concentration of acidity or alkalinity of river water remains essentially constant regardless of variations in the volume of flow.

(8) The changes in acidity or alkalinity of certain sections of the rivers and at different seasons are significant. The decided reduction in acidity or increase in alkalinity as the rivers flow through limestone areas is especially noticeable. The effects of the acid mine drainage entering the Lehigh, Schuylkill and Susquehanna Rivers rapidly disappear; the acid reacts with and is neutralized by the sewage and industrial wastes discharged into the rivers and by the limestone areas through which each river eventually flows.

(9) The investigation shows that the main streams and rivers that flow through the anthracite region are nearly always alkaline at all points within the anthracite region itself; moreover, short distances below the coal measures the rivers are permanently alkaline.

(10) Under present conditions acid mine drainage appears to be beneficial rather than detrimental to the municipalities along the banks and scattered over the drainage basins of the Lehigh, Schuylkill, and Susquehanna Rivers because of its neutralizing action on the highly alkaline sewage and industrial wastes in the receiving streams.

(11) Some of the undesirable effects are: (a) the sludge and other residues which settle on the river beds as a result of the chemical reactions between the acid and alkaline contaminants; and (b) the germicidal, inhibiting and neutralizing reactions are not controlled or consistent.

(12) There is no incentive or justification for treatment or diversion of acid mine drainage if the streams remain unsuitable for any use other than for disposal of sewage and industrial wastes.

(13) An estimate of the volume and acid content of the mine drainage discharged daily into the receiving streams flowing through the anthracite region is afforded by the data: 1,821,297 tons of water carrying a free-acid load of 445.69 tons (as H_2SO_4), and a total-acid load of 945.47 tons (as H_2SO_4), per day.

(14) Complete neutralization of acid mine drainage in the anthracite region, even if it were possible, would involve high costs for lime and its application to the water; artificial settling and separation equipment, or excavation and periodic cleaning of natural settling basins; and for disposal of the sludge formed in the chemical reactions of neutralization. It would burden the industry with exhorbitant if not prohibitive cost.

(15) Whether the abandoned anthracite mines should be sealed to exclude air from water (as has been done with many bituminous coal mines) and thereby attempt to prevent the formation of acid is doubtful. To seal effectively anthracite mines appears to be impossible because of the number of man-made openings to the surface, the many cave holes, the general subsidence over mined-out areas that has caused fissures in the strata between mine workings and ground surface, the numerous stripping pits exposing permeable coal beds to water and atmospheric air, and the large number of workable coal beds that have dips ranging from flat to vertical.

Mine drainage is a major problem in anthracite mines, and the difficulties encountered are becoming increasingly greater. No practical method of removing the acid properties of mine drainage is known, and it seems illogical that an additional burden of cost should be placed on the industry in an attempt to remedy an acid-water condition that, because of the sewage and industrial wastes that find their way into the receiving streams, is at present distinctly beneficial rather than detrimental. The control of stream pollution is the responsibility of all communities and industries that could be considered as offenders. Twenty-three references are given.

W. W. HODGE

Book Review

Public Health Engineering, Volume I. By Earle B. Phelps. John Wiley & Sons, Inc., New York. First Edition, 1948. Price $7.50.

The first volume of a two-volume work, the book contains 655 pages divided into two parts and 16 chapters, with appendix and index. Chapter headings are:

Chapter Heading	Pages
1—Man and His Environment	13
Part One—The Air Contact	2
2—Weather and Climate. Housing	12
3—The Air Supply of Enclosed Places	30
4—The Thermal Environment of the Human Body	24
5—Heating, Ventilation, and Air Conditioning	34
6—Illumination and Lighting	49
7—Atmospheric Pollution. Noise	26
8—Insects and Insect Control	62
Part Two—The Water Contact	6
9—Hydrology	16
10—Water Quality	55
11—Water Supply	49
12—Sewage Disposal and the Pollution and Self-Purification of Water Courses	46
13—Treatment of Polluted Waters; Principles	75
14—Treatment of Polluted Waters; Domestic Water Supply	45
15—Treatment of Polluted Waters; Sewage and Wastes	71
16—Rural Sanitation	29
Appendix	2
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The author is recognized as a pioneer investigator and an authority in the field of sanitary science. Assisting the author, Dr. Harry D. Pratt, Scientist, United States Public Health Service, wrote the chapter on Insect and Insect Control. Professor John M. Henderson, School of Public Health, Columbia University, revised the section dealing with drainage, and Professor C. J. Velz, Manhattan College, collaborated in the preparation of the whole of Part II, The Water Contact.

Public Health Engineering is the first volume of a two volume work which is announced as providing a "uniquely unified coverage of the entire field of environmental sanitation." Volume I, the environmental contacts of air and water, with Volume II, to be published later, devoted to the food contact.

The text has been "written primarily for the engineer who has presumably learned how to design and build, to teach him, in the light of present day knowledge of sanitary science, what to design and build and why. Its approach is through chemistry and the biological sciences, especially bacteriology and physiology. It stresses public health through engineering rather than engineering itself. This approach makes the text of service also to the medically trained student of public health.

In supplying the needed technical information for the medically trained reader the author has discussed the engineering elements of environmental control in an elementary—virtually sub-professional—way. There are several exceptions to this pattern, however, in which specific discussions reach technical levels all out of proportion to the treatment of the related subject matter. Notable examples of this are the discussions on yield of wells, principles of hydraulic separation, and high rate filter design, in which the author apparently lost sight of the fact that the book was "written primarily for the engineer who presumably has learned how to design. . . ." With these and one or two other exceptions, the engineering material presented is below that of the average college textbook level in comprehensiveness and technical detail.

The same evaluation can be made of the material included for supplying a chemical-biological approach for the engineer reader. In many of the items discussed, as for example the activated sludge process, the biological viewpoint is almost completely ignored and the subject treated primarily as an engineering process.

Medically trained students of public health will profit from the rather elementary treatment of the engineering aspects of environmental control. Sub-professional engineering personnel also may profit from the engineering treatment and the biological approach to the subjects covered.

S. C. Martin